CE-QUAL-W2 Model Recalibration and Simulations in Support of TMDL Activities for Weiss Lake, Alabama

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1. Introduction

1.1 Background

Weiss Reservoir is an impoundment on the Coosa River, created in 1961 by Alabama Power Company for hydroelectric power generation. The reservoir is located in Cherokee County in northeastern Alabama near the Alabama-Georgia state line (Figure 1). Major tributaries to Lake Weiss include the Chattooga and Little Rivers. Lake Weiss drains approximately 13,657 square kilometers, most of which is located in northwest Georgia.

Besides its use for hydroelectric power generation, the reservoir serves as a source of water supply for the town of Cedar Bluff in Alabama and is a well-known tourist destination for recreational fishing. The reservoir at full pool encompasses over 12,000 hectares of surface area and a volume of 38,000 hectare-meters. Full pool elevation is 172 meters above mean sea level and average depth of the reservoir is 3.1 meters.

A short residence time, a large overbank area and a small average depth characterize the reservoir. Water quality in the reservoir is characterized by high turbidity and significant phosphorus enrichment.

1.2 Prior modeling efforts

Weiss Lake was originally modeled with CE-QUAL-W2 by J. E. Edinger Associates, Inc. (JEEAI) in 1986 in support of thermal licensing issues at Plant Hammond on the Coosa River, just upstream of Weiss Lake (Edinger and Buchak, 1987a and 1987b). The Waterways Experiment Station made the definitive water quality application of CE-QUAL-W2 to Weiss Lake (Tilman, et al, 1999). There have been several updates to the datasets since the WES modeling effort: by Hesterlee at EPA, Glenn at Alabama Power Company, and Littlepage at the Alabama Office of Water Resources. The latter two efforts were supported by Buchak and Jain at JEEAI.

1.3 Scope of this study

The tasks anticipated in this study were:

- Develop boundary conditions and set up Version 3 of CE-QUAL-W2 to run long term simulations for 11 years from 1991 to 2001
- Calibrate the model using data for all 11 years
- Provide assistance in application of the model to (Total Maximum Daily Load) TMDL development

The study was carried out in close technical collaboration with EPA. Analyses and technical emphasis areas were jointly developed with EPA staff and were allowed to evolve as the modeling progressed. Work products from prior modeling efforts were used to the extent possible and appropriate.

2. Model setup

2.1 Input data

The types of input data required for a CE-QUAL-W2 model application are shown below. The corresponding typical CE-QUAL-W2 filenames are also shown, and they are listed in the order in which they are generally developed.

Input data type	Corresponding CE-QUAL-W2 filename	Time step at which required
Bathymetric data	Bth.npt	- not applicable -
Time series meteorological data	met.npt	Hourly
Time series data for quantity	qin.npt, qtrib.npt, qdt.npt, qwd.npt, and qout.npt	Daily
Time series data for water temperature	Tin.npt, trib.npt, tdt.npt	Hourly or daily, can be estimated from meteorological data
Time series data for water quality	cin.npt, ctrib.npt, cdt.npt	Hourly, usually developed from sparse observations
Model coefficients and simulation options	W2_con.npt	Variable, application-specific and user defined. Most model coefficients and options are not a time varying input

Because CE-QUAL-W2 steps through time from a defined initial condition by accessing simultaneous boundary condition data, it requires that time series boundary condition data be continuous. Computationally, the model has a binary switch that either interpolates between records, which could be months apart, or uses the “last available value” for the input parameter.

2.2 Model geometry

Bathymetry was made available as a model grid from previous modeling efforts, and was not expected to require any change during this calibration. This grid was recognizable as the product of earlier refinements by JEEAI. The Elevation-Area-Volume relationships of the model grid and the standard reservoir curve available from Alabama Power Company (APC) are shown in Figure 2.

In this application, many 11-year simulations were to be routinely carried out and emphasis was on water quality calibration, hence short simulation times on the computer were considered more important than a detailing of hydrodynamic behavior. Accordingly, the grid was further simplified into a smaller number of segments and layers. Simplifications to the grid are shown as a sequence of images in Figure 3 through Figure 5. The grid file was also modified for format differences between Version 2 and Version 3 of CE-QUAL-W2.

2.3 Meteorological data

The meteorological data for the 1991-2001 study period were developed from two sources, the National Weather Service (NWS) station at Rome, GA and the Georgia Automated Environmental Monitoring Network (GAEMN) station at the College of Agriculture and Environmental Sciences of the University of Georgia, also in Rome.

The NWS station (WBAN 93801) is located east of Weiss Lake at the R. B. Russell Airport, 194.8 m above sea level (latitude 34°21'N, longitude 85°10'W). Hourly (or more frequent) observations of air temperature, dew point temperature, wind speed, wind direction, and cloud cover are available. These variables are used to compute the seven individual surface heat exchange components, shortwave solar radiation, reflected shortwave solar radiation, long-wave atmospheric radiation, reflected long-wave atmospheric radiation, back radiation, evaporative heat loss, and conduction.

The largest term in the surface heat exchange calculation is shortwave solar radiation. It is generally computed from cloud cover data. The difficulty with the NWS dataset is that of the 89667 records available for the 11-year period, 46,703 of the records have no cloud cover data. Furthermore, cloud cover data after 31 March 1997 are taken by the Automated Station Observation System (ASOS). ASOS implementation by the NWS began in the mid-1990's. Prior to this date NWS stations used visual observation of cloud cover. After ASOS implementation, cloud cover observations are taken with a laser device. The device scans the vertical only to 12,000 ft and therefore would report no cloud cover for cloud layers higher than 12,000 ft. This limitation can result in a systematic overestimation of the solar radiation rate. Because of this limitation, direct observation of solar radiation rate is preferred to cloud-cover based computations.

The GAEMN station at Rome (Floyd County) is located east of Weiss Lake 188.4 m above sea level (latitude 34°21'N, longitude 85°7'W). The station has collected air temperature, humidity, wind speed and direction, and solar radiation rate beginning on 14 July 1992. The frequency with which data are collected was changed from hourly to every 15 minutes on 5 January 1996.

Each of these datasets was transformed into the standard W2 format using the W2Met tool developed by JEEAI. To obtain the most complete dataset for 1991-2001, the NWS record was combined with the GAEMN record as follows:

Period	Air temperature, dew point temperature, wind speed, wind direction, and cloud cover	Solar radiation	Frequency
1/1/1991 to 7/13/1992	NWS	Computed from NWS cloud cover	Once per hour
7/13/1992 to 1/5/1996	GAEMN	Observed	Once per hour
1/5/1996 to 12/31/2001	GAEMN	Observed	Four times per hour

Solar radiation data for the 1 January 1991 to 13 July 1992 data are suspect since no cloud cover values were recovered for this period and a value of 5/10th cloud cover was assumed.

2.4 Inflow quantity

Daily inflow records were available at three stations in the Weiss Lake watershed.

Agency	Station ID	Station Name
USGS	02397000	COOSA RIVER NEAR ROME, GA
USGS	02398300	CHATTOOGA RIVER ABOVE GAYLESVILLE AL
USGS	02399200	LITTLE RIVER NEAR BLUE POND AL

Inflow data not yet available from the internet were supplied by EPA staff as unit values as acquired from USGS personnel. The most recent data were supplied as provisional values. These unit value records were processed into daily average inflows for use in the model.

A simple drainage area proportion method was used to develop the daily inflow for ungaged streams. Drainage areas were obtained from gage descriptions at the USGS web site (www.usgs.gov) and from the flow estimation spreadsheets made available from previous modeling work. Coosa inflow was increased by approximately 8% to reflect the additional Coosa River drainage area between the location of the gage at Rome and the model upstream boundary near the AL-GA State Line.

2.5 Water balance

Water balance refers to dynamically balancing the magnitude of various inflows and outflows so that observed water surface elevations are reproduced in the model grid. This may be considered a "calibration" to observed elevation, but is presented here as a step in setting up of inflow and outflow files for the model.

The inline water balance calculation is an implementation of the following equation:

$$\frac{dV}{dt} = Q_{in(unknown)} + Q_{in(known)} - Q_{out} - Q_{evap}$$

which can be rearranged as

$$Q_{in(unknown)} - Q_{evap} = \frac{dV}{dt} - Q_{in(known)} + Q_{out}$$

where

$Q_{in(unknown)}$	=	unknown inflow rate, to be allocated to distributed tributaries, $m^3\ s^{-1}$
Q_{evap}	=	evaporation rate, $m^3\ s^{-1}$ (can be computed directly in CE-QUAL-W2)
$\frac{dV}{dt}$	=	change in storage, $m^3\ s^{-1}$
$Q_{in(known)}$	=	known inflow rate, computed as the sum of the gaged inflows, $m^3\ s^{-1}$
Q_{out}	=	total outflow rate, $m^3\ s^{-1}$

The change in storage is computed on a daily time step as follows

$$\frac{dV}{dt} = \frac{A \cdot (el_{today} - el_{yesterday})}{86400}$$

where

A	=	the surface area of the reservoir, m^2
el_{today}	=	water surface elevation at the start of the current day, m
$el_{yesterday}$	=	water surface elevation at the start of the previous day, m

$Q_{in(unknown)}$ can be either positive (additional inflow is required to reproduce the observed water surface elevation) or negative (additional outflow is required). In practice known inflow rates can be decreased in the latter case, or some combination of the two possible corrections can be implemented. For the Weiss Lake application, additional inflows and outflows were allocated to the "distributed" inflow for Branch 1 (mainstem). The computed values of $Q_{in(unknown)}$ (qcorr as programmed in Fortran) are algorithmically limited in proportion to the known inflows in the case of $Q_{in(unknown)}$ being positive, or in proportion to the known outflows in the case of $Q_{in(unknown)}$ being negative. This approach allows some deviation from the observed water surface elevation so that any of the corrected flows do not become unrealistically high due to noise in the observed elevation record.

The above calculations were implemented as an add-on module to CE-QUAL-W2 Version 3. The module is described in Section 2.11 "Code changes specific to Weiss Lake".

2.6 Inflow water temperature

Inflow water temperatures for the Coosa River and other branches were developed from USGS observations. All of the USGS observations had periods of missing data. The observations were therefore augmented by temperatures computed directly from meteorological data using the response temperature computation, described below. Augmentation is necessary because CE-QUAL-W2 will interpolate from the previously known value of the boundary condition data. This behavior would cause erroneous results during long periods of missing data. The Coosa River had the most observations and, since it represents the largest inflow to Weiss Lake, inflow temperatures for it were developed separately from the inflow temperatures for the remaining branches. In past applications, Coosa river temperatures were used for all inflows to Weiss Lake.

2.6.1 Coosa River inflow temperatures

Data from USGS Station 2397530 (contained in the files "COOSA.TEMP.DAT" and "STATELINE.WT.FF.00.DAT") were used to generate the Coosa River inflow temperature input file for CE-QUAL-W2 as follows.

COOSA.TEMP.DAT contained daily mean, max and min values of water temperature for the period 10/1/1989 to 9/30/1999. The mean difference between the max and min values over the 1991-1999 part of this record (2992 values) was 1.3°C, with a standard deviation of 0.92°C. This small variation allowed direct use of the mean value (one value per day).
STATELINE.WT.FF.00.DAT contained hourly data for the period 10/1/1999 to 9/30/2000, with two periods of missing data: late May-early June (5/12/00 to 6/7/00) and late June-mid July (6/23/00 to 7/17/00). Additionally, the record ended on 9/30/2000; while the study period extended to 12/31/2001.

A simple water temperature computation, called the response temperature model, was used to compute inflow temperatures for comparison to these observations. The response temperature model is described in Appendix 1 – Response Temperature. For the application of the response temperature to the Coosa River, the best fits to mean daily observations (Figure 6 and Figure 7) were obtained with D = 4 m; no shading; windspeed function: Brady, Graves and Geyer; effective windspeed coefficient 1; winter water temperatures were limited to a minimum of 5 C. No groundwater inflows were used. All the observations beginning with 1/1/1991 were used in the calibration.

The following table summarizes the development of the Coosa River water temperatures for the study period.

Period	Observations	Missing data	Source of substitutions for missing data
1/1/1991 to 9/30/1999	Mean daily values in COOSA.TEMP.DAT	None	--
10/1/1999 to 9/30/2000	STATELINE.WT.FF.00.DAT	5/12/00 14:00 to 6/7/00 14:00, 6/23/00 9:15 to 7/17/00 21:00	Response temperature based on GAEMN met data
10/1/2000 to 12/31/2001	(none available)	All	Response temperature based on GAEMN met data

2.6.2 Inflow temperatures for the remaining branches

Temperature observations available as discrete samples (approximately monthly) from three non-Coosa River USGS stations in the Upper Coosa basin. These stations are

Station Number	Site and Location
2398300	Chattooga River above Gaylesville AL
2399200	Little River near Blue Pond AL
2400100	Terrapin Creek at Ellisville AL

These three stations were the only non-Coosa River stations with a long time-series record that also intersected with 1991-2001. Data from these three stations were amalgamated as though from a single station and plotted as a time series. The response temperature described earlier was calibrated to these data, and used to fill in the missing data periods. The best fits (Figure 8 and Figure 9) were obtained with the following parameters D = 3 m; 50% shading; windspeed function: Brady, Graves and Geyer; effective windspeed coefficient 1; winter temperatures were limited to a minimum of 5 C; no groundwater inflows were used.

2.7 Inflow water quality constituents

2.7.1 Background

Estimation of inflow constituent loads (or equivalently, concentrations) is one of the most important components in the development of a water quality model application. Its importance derives from the fact that nutrient loads are usually critical to the prediction of in-reservoir water quality. Even in cases where aspects other than the nutrient load control the reservoir water quality, quantifying the effect of nutrient loads (or the lack of such an effect) may be an important regulatory objective. In this application, inflow load estimation was especially important because of the intended use of the calibrated model in a TMDL allocation.

However, load estimation is problematic because the needed data tend to be extremely limited. The field data for boundary water quality are collected only at a few points in time, typically monthly. But the model expects at every time step a value for the water quality at the grid boundary. The interpolation of field data to this level of resolution is inappropriate when done from single point observations spaced one month apart.

There is research literature devoted to this problem, but the problem of data insufficiency remains, except in a few cases where data are found to follow some relationships with variables (e.g. flow) that are either known or are more reliably interpolated at every time step. Unfortunately, Coosa River water quality data do not show any such relationships.

Many approaches were attempted to estimate the boundary water quality in this application. These included trying new equations in lieu of the traditional power relationship assumed between flow and concentration, use of aggregate and lagged flow history as a predictor instead of concurrent flow, and stratification of data along various seasons and inter-annual periods besides flow. For brevity and focus in this report, only the approach finally selected and its further refinement in consultation with EPA is described below.

2.7.2 Rationale

One of the key aspects of the approach followed here was the idea that the total nutrient budget at the boundary is more important than the speciation of the nutrients into different constituent forms. Additionally, with the regulatory focus being limited to two compliance points (WEISS2 and WEISS1) that are respectively at the middle and downstream end of the reservoir, the speciation at the boundary was considered to be of even lesser importance. Still, approximately correct speciation was applied. Effects of this assumed speciation were attenuated by the time water reached the upstream compliance point. In essence, the calibrated model itself "speciated" the nutrients in the upper third of the reservoir to provide an accurate as well as seasonally and diurnally varying speciation and total load boundary condition to the downstream two thirds of the reservoir.

With this assumption, the load estimation process was reduced from estimating a high-resolution time-series of individual nutrient forms to estimating essentially four time-series: Total Phosphorus (TP), Total Nitrogen (TN), Inorganic Suspended Solids (TSS) and Total Organic Carbon (TOC).

2.7.3 Statistical estimation method

The method for determining the time series for water quality constituents is usually to look for statistical correlation of these quantities with one or more other covariates that are known at a daily or better time scale. A typical covariate is flow, and time itself (as season, year etc.) can represent another set of covariates. Rather than develop custom correlations for each constituent, it was sought to develop a generalized regression equation, where individual coefficients could reflect differing importance of the various covariates for each constituent.

Many choices of variable transformations, use of a lagged flow record, statistical estimation methods and aggregation and stratification choices were investigated with the water quality data at State Line station. Given the number of data points, and interactive assessment of the relationships in this dataset, the combination of best results and most reasonable assumptions was judged to be: 1) estimating a log-log relationship of constituent concentration with concurrent average daily flow rate, 2) using all the field data for this relationship, i.e. without any stratification, 3) adding modifying factors for growing season, year, and with the interaction term included.

Past applications to the lake as well as applications to other reservoirs have typically used for the inflow boundary concentration boundary a simple linear interpolation from one sampled date to the next. It is known that the river water quality does not follow such behavior in time, but such an approach has been taken for lack of a better alternative. The current technique substantially improves the physical basis of estimation of the boundary concentrations.

The Generalized Linear Model (GLM) procedure in the statistical package SPSS Version 9, which includes linear regression under its umbrella of techniques, was used for the above estimation. Coefficients fitted by SPSS were imported in Excel to compute the predicted values, and were checked against the predictions made within SPSS. Details are omitted from this report, but the SPSS datasets, command history, and output files are included in the technical materials accompanying the report. For readers without access to SPSS, the output is included as an exported HTML file that can be read by any web browser on the enclosed CD.

The estimation procedure simulates the seasonal effect as a two-way variable (growing season = yes/no) and the inter-annual effect for each individual year, and an interaction term for these two variables. All data points are used to estimate the effect of flow. Thus the procedure is general with respect to how well the constituent is correlated with flow and isolates seasonal and inter-annual trends correctly for either case.

2.7.4 Results

Figure 11 through Figure 14 show the results of the fit for the four total constituent species estimated. The TP time series does not show much short-term (day to day) variation because the relationship with flow was not significant. This time series (Figure 11) therefore reflects largely the step function implied in moving from one season-year combination to the next. At the other extreme, the TSS data (Figure 14) showed a significant relationship with flow and thus generates a greater dependence on flow, but without losing the inter-annual and seasonal variation. The flow and seasonal variation of TN and TOC was intermediate between that of TSS and TP. Plots of estimated marginal means (attached as SPSS output files on CD) are also a useful way to visualize the estimated inter-annual effect in the data for the growing season and the non-growing season separately.

The results for TP were unusual. Generally TP is strongly correlated with flow, as most of phosphorus is associated with sediment. A possible reason for the lack of any relationship with flow is that the river water quality is dominated by upstream reservoir operations. Integration of this model with models for upstream reservoirs and the intervening river section may be very helpful to improving the boundary condition.

Daily time series of average daily load (=flow x concentration) is shown in Figure 15.

2.8 Modified inflow water quality

The analyses developed in the preceding sections were further modified at a later stage in the application. These modifications were made consequent to discussions with EPA staff and with additional insights into the estimation issues and techniques.

Three modifications were made:

- Instead of modeling the effect of each season-year combination as an independent factor, effects of time were modeled as a month factor and a year factor and no interaction term was included. Thus a month-month variation described the seasonal variation in the concentration. As before, this seasonal variation was scaled up or down for each year of analysis independently, i.e. no trend was assumed across years.
- Allocation of the total estimated nutrient into available and organically bound fractions was done in a way that preserved the constant organic matter stoichiometry (an assumption in CE-QUAL-W2) as well as maintained realistic concentrations of the available forms.
- A smoothing procedure was developed that honored the monitoring data exactly in the vicinity of the observations. This procedure used weights for the model estimates and

data based on local distance from the monitoring date as well as the overall correlation coefficient of the model. Figure 16 illustrates the procedure and how it improves on a simple linear interpolation approach based entirely

All these computations are documented in the excel spreadsheets available on the enclosed CD. The updated time series are shown in Figure 17 through Figure 22.

Inflow constituent concentrations for other inflows (branch inflows, distributed inflow) were developed as simple constant values for each constituent, developed from inspection of the limited field data available. Too few data were available to estimate a time series of these concentrations. Little River is known to have a low level of pollution. Given the limited data, all other inflows were assumed to have water quality identical to Chattooga River estimates.

2.9 Initial conditions

Long simulations are less affected by initial conditions, especially in a short residence time reservoir like Weiss Lake. Hence, it was considered sufficient to choose an approximate initial condition for each constituent that was also uniform in the longitudinal and vertical direction. This type of initial condition was used only for long simulations that started in January 1, 1991.

Short simulations were carried out for explorations related to calibration experiments and for debugging numerical difficulties during model setup. For these simulations, an "approximate restart" capability was added to the code (see 2.11 below) to reduce the spin-up time requirements for these simulations.

2.10 CE-QUAL-W2 source code

Support and enhancement for Version 2 of CE-QUAL-W2 has been discontinued at the US Army Corps of Engineers, Waterways Experiment Station, where the code resides. Version 3 of the model has been under development for a few years and interim releases have been made available for applications.

Version 3.0 of the release dated Dec 24, 2001 was used in this application. Since there is no mailing list announcing releases of newer versions, availability of any newer version was checked periodically at the current official release website www.ce.pdx.edu/w2 as well as through direct contact with the developers of Version 3.x.

No formal releases of Version 3.0 code have been made since Dec 24, 2001. An undocumented release was made available in June 2002 in response to a bug report sent in to the developer (Dr. Scott Wells at Portland State University). This release showed few changes from Dec 24, hence no update was made to the source code for this application. A Version 3.1 interim release is currently available from one of the developers as of this writing, but because it is not a formal release, and has a different module and variable declaration structure from Version 3.0, it will require a larger testing and validation effort than is possible within the present study.

2.11 Code changes specific to Weiss Lake

The module and variable declaration structure was simplified and subroutines broken out into a number of separate files to aid compilation.

To help with being able to restart and debug short periods of simulations, an "approximate restart" capability was added. The restart capability appears to have been carried over into Version 3 code from version 2, but is not upgraded to reflect all new global variables in Version

3. Exact reproducibility of restarted simulations would require saving all the global variables in the code that influence any state variable in the next time step. In practice, approximate restarts worked very well, as the intent was to only to supply a horizontally and vertically varying initial condition to a simulation without requiring a few months of spin-up each time to develop the flow and water quality gradients.

Water balance computations were done as described in Section 2.5 Water balance. This code is written as an add-on module readily portable to other applications. At every user-definable time period, typically daily, the current modeled water surface elevation is compared to the observed elevation read from an external file. It is hypothesized that the inflows and outflows are uncertain, and a volume of water representing the water elevation discrepancy is computed and applied every time step as a flow distributed over the interval from current time to the time at which the comparison is next scheduled to be made. Computed net addition of water to the reservoir is added in as a spatially distributed inflow and a net subtraction of water added as an addition to the turbine outflow. To avoid unrealistic corrections, as well as to avoid undershoots and overshoots, the code is supplied with four user-set parameters: 1) upper limit to corrective flow as a fraction of the total flow, 2) frequency of comparison, 3) segment in which comparison is made, 4) minimum correction that can be applied regardless of inflow or outflow. The last parameter is helpful to allow smooth corrective inflows in highly variable outflows in a peaking hydropower reservoir like Weiss Lake.

Code was also modified for output and visualization purposes. Most input read statement formats were converted from a fixed width format (F8.0) to a list directed format. Most model inputs are developed in excel spreadsheets and then exported to model input files. The list directed format supports comma as a delimiter, making export from spreadsheet more convenient.

The complete code as used in this application, along with associated "Compaq Visual Fortran" workspace and project files, is included in the enclosed CD. All changes to the Version 3 source code were annotated. The changes are commented with the date and initials of the author/firm.

3. Model calibration and performance analysis

3.1 Calibration approach

The calibration process sought to preserve the physical relevance of the parameters and produce reasonable dynamic behavior of the constituents, while seeking the best possible fit to the field data.

An anecdote from the current calibration effort illustrates the importance of maintaining physical relevance in a model and avoiding a pure curve-fitting approach. In early simulations, nitrate levels were found to consistently run higher than expected. Verifying the boundary condition and conducting analyses of sensitivity to parameters suggested that nitrogen dynamics was perhaps not being simulated correctly. Rather than simply fitting the model to field data by tuning the coefficients, model code was carefully examined to assess the value of various terms in the equations. It was found that nitrate uptake was effectively being rendered zero due to a variable declaration error. In a purely curve-fitting approach, this process inaccuracy could have been masked by increasing the nitrate decay rates and by the flushing effect in a low residence time reservoir. Careful attention to process level detail thus led to improvement in the model reliability and usability.

The model was calibrated to all years simultaneously. Some modelers break up the dataset into a calibration database and a verification database. Our opinion is that such an approach is artificial and reduces the utility of the verification data, unless the calibration is repeated with the entire set of observations after verification is done. With the current approach of using the entire set of data for calibration, verification can still be done by selectively looking at any part of the observation record. Such selection can be done not just by year, but also along any other dimension of the field data like season, flow regime, temperature, collecting agency, or depth.

3.2 Calibration data and assumptions

A large number of data were available from the 11-year record for comparing to the model. Vertical profiles of DO and temperature were available on many dates in all years. Other water quality parameters like Chlorophyll a (Chla) and nutrient species were available as samples taken as composites from the photic zone. In addition, sediment flux and water column respiration measurements were made available for one date in summer of 2001.

It was assumed that the surface layer of the model adequately simulates the photic zone composites of water quality. The composites are taken over approximately 2 m. Model layers are nominally 2 m thick, with the surface layer varying in thickness somewhat as the water surface moves up and down. A sampling of the values in the top few layers of the model, probed at various locations and seasons, suggested that any systematic large error was not likely to be introduced by using this equivalence.

Additional Visual Basic code was written around the software W2Studio (JEEAI preprocessing and visualization tool for CE-QUAL-W2) to support computation of profile statistics from the model output. The time series comparisons were done using Microsoft Excel.

Given the large amount of data in this application, several hours of simulation time, and the decision to carry out calibration manually, not all data could be evaluated simultaneously. Instead, the model was refined iteratively by focusing on a subset of data at a time, using the modeler’s experience and judgment after each run to decide what data to focus on, and what calibration experiment to carry out for the next few simulations. Such an approach is subjective but allows for the most technical oversight on the calibrated parameters.

The model boundary conditions and kinetic coefficients were iteratively refined till the seasonal dynamics of the photic zone composites were approximately reproduced for most of the predicted and observed state variables and from one year to the next in continuous simulations. Flux measurements were helpful in assessing the magnitude of the parameters, but were judged to be too few to use for constraining the parameter choices directly. Profile data for temperature and dissolved oxygen were periodically checked for approximate consistency, but most attention was focused on seasonal development of the water quality constituents in the photic zone, and their variability across years as judged visually in time series plots. Because of the large number of profiles (237) available to the calibration, the profile comparisons were reviewed only as the absolute mean error (AME), root mean squared (RMS) error and mean error (ME) statistics of the individual residuals from each profile. These statistics were ranked and sorted by station, year and magnitude of error to discern patterns, but individual profiles were visualized only selectively.

3.3 Final calibration

The control file for the final calibration is reproduced in Appendix 2 – Model Control File. The use of the original file format documents the model coefficients and assumptions in a form most directly familiar to experienced model users, and most comparable to model inputs for prospective model users. Appendix C of the Version 3 User's Manual (also enclosed on the CD) describes the individual parameters, units and physical interpretation. Comments on selected parameter values that may be helpful to other modelers are embedded within the control file in a different font.

Figure 23 through Figure 30 show the model output for the 11-year simulation period for the two surface layers at the two compliance stations, with photic zone composite field data plotted where available. The plots show reasonable behavior of constituents, with values well constrained within reasonable limits and close to observed data in most cases.

Calibration of water quality models is more an art than a science. There are no established or recommended procedures for water quality model calibration. It is especially difficult to proactively develop a standard procedure for calibrating a coupled hydrodynamic and water quality model for a highly dynamic, low residence time system like Weiss Lake.

Figure 31 shows the age of water at the two compliance stations, illustrating the dynamic nature of the system. Age of water varies substantially across years and seasons, and is rarely more than 40 days at the most downstream compliance point, which is also the most downstream location in the reservoir. As expected, the maximum age occurs during the summer low flows, and this maximum varies from year to year. However, there can be periods of rapid flushing during these relatively stagnant periods, thus pointing out the need for a dynamic model, as well as a sampling plan that matches the residence time scale of the reservoir.

It is certainly possible that a repeat of the calibration process, even by the same modeler, will lead to a different set of parameters. However, given that multiple years and seasons are represented in the data, and that simulations were continuous over 11-years, it is unlikely that an acceptable fit can be obtained with widely differing representations of the relative importance of various processes.

An assessment of the performance of the calibrated model for current purposes is discussed next.

3.4 Performance analysis

Three different types of analyses illustrate the performance of the calibrated model.

3.4.1 Regressions of predicted vs. observed Chla

An assessment of a model's prediction performance is in how well it predicts past measurements. In other words, how much would one have been better off in having the model than in not having it? It is appropriate to compare the model to the case where one relies on pure chance, as this is the absolute lowest limit to predictability. All candidate models can be conveniently compared to this lower limit.

Then, an easy and objective measure of performance relative to pure chance is through a regression between a predicted and observed quantity. The r^2 of such a regression is the percent of total variance that is explained by the model. A value of 0.0 would indicate that the model did no better than pure chance at predicting past observations, and a value of 1.0 would indicate that the model completely explained all the variation in the observations. The slope and intercept of the regression should ideally be 1.0 and 0.0, respectively.

The current intended objective of the model is its use in developing a TMDL allocation, based on a regulatory endpoint that is defined in terms of Chla. Therefore, r^2 was computed for Chla observations and predictions at the two compliance points.

Due to incomplete monitoring data available for the 2001 growing season, EPA did not consider the year 2001 in the TMDL development (Craig Hesterlee, pers. comm.). To parallel that decision, the above model comparison statistics were also generated while excluding the year 2001. The r^2 values were found to be higher with this subset of years, i.e. for 1991-2000. The improved and original values are tabulated below:

Station	% variance explained for 91-01	% variance explained for 91-00
WEISS1	0.32	0.37
WEISS2	0.26	0.38
AVERAGE OF WEISS1 and WEISS2	0.41	0.41

Average of the two stations was taken to reduce the effect of any transients in the observations and model output, while retaining the overall seasonal effect. Averaging of the Chla value at the two compliance points was also considered to be a possible interpretation of the ADEM water quality standard.

3.4.2 Frequency distribution comparisons

For developing the TMDL, the model was to be run with a series of load reduction scenarios. The regulatory end point applicable to the TMDL is that the growing season (April 1 – October 31) average of Chla be less than 20 µg/l. Thus, another criterion that maps more directly to this intended use of the model is whether the model results have the same frequency of exceedance of this standard as the observation record.

Since model output is available daily, but observations only sporadically, model results could be aggregated daily or only for dates corresponding to the observation dates. Figure 32 through

Figure 34 present cumulative frequencies and histograms of the predicted and observed Chla distributions taken at the approximately 50 sampling dates over the 11-year period at the two stations. The table below shows the percent of “samples” that exceed 20 µg/l in the pool of observations and model predictions for the sampled dates.

Station	% exceedance in observations	% exceedance in the model for sampled dates
WEISS1	40%	26%
WEISS2	31%	33%
AVERAGE OF WEISS1 and WEISS2	25%	27%

Note that the selection of 20 µg/l level is arbitrary. The above percentages are not intended to indicate non-compliance of the standard at these locations, because the standard is written in terms of growing season averages, not in terms of exceedance frequencies.

Other comparisons of predicted and observed Chla, using growing season aggregates for the years judged relevant to a TMDL, have been made by EPA and reportedly show excellent agreement (Craig Hesterlee, pers. comm. 2002).

3.4.3 Temperature and dissolved oxygen profile comparisons

Residuals were computed from each profile of field data for temperature and dissolved oxygen (DO). The modeled value was interpolated to the depth of each observation. The computations were coded in Visual Basic as an add-on program to W2Studio (JEEAI toolkit for CE-QUAL-W2). The residuals were summarized into three statistics for each profile. Average error (ME) indicates overall bias in the prediction, with a positive number indicating model prediction being higher than observed. The sign of the residual is as computed using “Modeled – Observed”. Absolute mean error (AME) and root mean square error (RMS) respectively drop the sign to indicate a measure of distance between model predictions and observations. Since RMS uses square of the residuals, it weights the larger residuals more heavily than does AME. RMS is thus expected to be larger than AME.

The table below shows the composite error statistics pooled across all locations and dates for which data were available from two independent data sources. EPA supplied both the datasets. APC refers to data collected by Alabama Power Corporation, and WRDB refers to all data consolidated into WRDB, the data management and visualization software developed at EPA Region IV. Temperature is in units of degree Centigrade, and DO is in units of mg/l.

Statistic	TEMP (APC)	DO (APC)	TEMP (WRDB)	DO (WRDB)
ME	-0.41	-1.52	-0.26	-1.15
AME	0.85	1.81	0.78	1.60
RMS	0.91	2.05	0.83	1.84

The results suggest that the final calibration has the model under-predicting temperature slightly and DO somewhat more significantly. Minor modifications of parameters may be able to reduce these errors. These error statistics were monitored, but not focused on as a calibration target during this calibration. It is conceivable that small changes to parameters will be able to further reduce these error statistics without substantially altering the Chla and nutrient seasonal development at the surface as illustrated in the time series plots.

Figure 35 shows that there was no trend in the residuals from one year to another. "Appendix 3 –Temperature and dissolved oxygen profile comparisons" contains the residual statistics for each available profile.

3.5 Overall model assessment

The goodness of fit statistics were found to be sensitive to the time of day model output was taken. Intra-day and intra-week transients of boundary water quality are likely to have the same effect on model predictions at the compliance points. Intra-day variations are not estimable and intra-week variations are barely estimable from the river water quality sampling data. Short time and space scale patchiness of algal concentration may also occur at the sampling stations, and also be transported into the sampling area from other areas. Photic zone depth was estimated from secchi depth in the field, and approximated in the model by the surface layer thickness which varies within 1-3 m, and independently of current light extinction coefficient at the surface. in the presence of these factors that add unexplainable variance to the Chla observations, it is notable that the model explained 30-40% of the observed variance in Chla.

The model calibration focused on Chla, and at the two compliance points, because of the immediate intended use of the model in TMDL allocation that was based on a regulatory standard written in terms of Chla at these two locations. The model should not be used for other purposes without a reassessment and recalibration effort.

3.6 Recommendations

In the final analysis, a model can only be as good as the data it is based on, either the data used for calibration or data used as time varying inputs for which predictions are to be made. More data need to be collected to better characterize the lake boundary inputs and additional tributary sampling should be included.

Integration of Weiss Lake modeling with upstream watershed and reservoir models would help provide the best possible available boundary estimates with the given monitoring data.

In-reservoir dynamics should be captured by some continuous monitoring data to serve as a test of the model's ability to capture processes at the hourly scale at which they are developed in the model. Monthly or less frequent grab samples are not appropriate for constituents like Chlorophyll that change rapidly on a diurnal basis. Additional flux measurements like the ones carried out during 2001, and that include a few primary production measurements will also be helpful to a future modeling effort.

Concurrent with the data collection, a useful enhancement to the model will be in upgrading the water quality kinetics of this public domain model. Several enhancements were considered during model calibration, but their implementation and testing was not within the scope of this study. It is possible that such enhancements will allow more of the observed inter-annual and seasonal variation to be captured.

As a specific example, a fixed stoichiometry of nutrient, organic carbon and chlorophyll in the model was a constraint in setting up and in calibrating the model. Stoichiometry assumptions directly affect a regulatory application because models have to implicitly relate various model inputs and outputs in four different currencies of N, P, organic matter, and Chla. Allowing the stoichiometry to vary either as an empirically determined external input, or mechanistically modeling some of the variation, may improve the confidence in relating a nutrient input (management action) to a Chla concentration (regulatory end point) which are two different currencies linked to each other through various water column transformation processes.

For ongoing monitoring, a combined modeling-monitoring study could be designed that rapidly incorporates monitoring data in the model. Cost of the modeling component is typically small relative to the monitoring component, thus sensitivity simulations could be used to optimize the monitoring component for cost and predictive utility.

4. Conclusions

The CE-QUAL-W2 Version 3 model application to Weiss Lake was set up successfully for the entire 11-year period from 1991 through 2001. Some model inputs were not available beyond September 30, 2001. Tributary load estimation for Coosa River was done with a method that improved on the current practice. It estimated a continuous concentration time series that replicated the observed river concentration on a sampled date, but smoothly transitioned to a regression-based estimate as one moves away from a sampled date into the frequently large period between observations. The same set of equations and protocol was used for all four loads estimated (totals for phosphorus, nitrogen, organic carbon and suspended solids).

Considerable effort was spent investigating various regression-based approaches. The selected equations included seasonal and inter-annual effects to help assess the variation of nutrient load at these two time scales.

While analysis and reporting of historical loading patterns was not part of the study, this effort was required to develop the best possible boundary input to the model prior to calibration. The developed time series and the estimating equations are available in an easily accessible spreadsheet format for any further analysis on historical nutrient and organic matter loads in the Coosa River across the State Line.

The calibrated model captured the overall seasonal dynamics of three algal groups in each year, further increasing the confidence that algal dynamics have been represented adequately. Another key feature captured by the model is the dominance of N limitation on algal growth throughout the season. This feature is consistent with the finding of the feasibility study report (Bayne, 1993).

Analyses of the calibrated model's performance were done using regression metrics and tabulation of cumulative frequencies for predicted algal concentrations, which is the current water quality standard being used for TMDL development. The model was found to have good predictive capability for algal concentration. Regressions of predicted and observed algal concentrations showed that 30-40% of the variation in the observations was explained by the model. Frequency distribution of the same two quantities also showed agreement that ranged from adequate to excellent. Other comparisons made independently by EPA that were based more closely on the growing season averages used in TMDL development have reportedly shown remarkable agreement between model output and observations.

All the tasks in the scope of work were successfully accomplished. EPA staff closely monitored the progress of the modeling effort. The model was used for TMDL proposal development by the agency when the calibration was considered acceptable.

5. References

Bayne, et al. 1993. Weiss Lake Phase I Diagnostic and Feasibility Study, Department of Fisheries and Applied Aquacultures, Auburn University.

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Tilman, D. H., Cole T, M. and Bunch, B. W. 1999. Detailed Reservoir Water Quality Modeling (CE-QUAL-W2), Alabama-Coosa-Tallapoosa/Apalachicola-Chattahoochee-Flint (ACT/ACF) Comprehensive Water Resource Study. U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199. April 1999.

EPA Region 4. 2000. Lake Weiss Two-Dimensional Eutrophication Model Revision Report. EPA R4 Water Quality Assessment Section Weiss Reservoir TMDL Supplementary Report. July 2000.

6. Appendix 1 – Response Temperature

Response temperature is defined as the temperature a column of fully mixed water would have if surface heat exchange were the only active heat transfer process (i.e., water temperature "responding" only to surface heat exchange). The rate of surface heat exchange can be computed from air and dew point temperature, wind speed, cloud cover, solar radiation, and atmospheric pressure.

The rate of change of response temperature can be written in terms of the net rate of surface heat exchange as

$$D\frac{dT}{dt} = \frac{R_{net}}{\rho c_p} \qquad \text{Equation 1}$$

where

D	=	mean depth of the water column, m
T	=	water column temperature, C
t	=	time, s
R_{net}	=	net rate of surface heat exchange, W
ρ	=	density of water, 1000 kg m^{-3}
c_p	=	specific heat of water, 4186 J kg^{-1} $°C^{-1}$

Further,

$$R_{net} = R_s - R_{sr} + R_a - R_{ar} - R_b - R_e - R_c \qquad \text{Equation 2}$$

where

R_s	=	shortwave solar radiation, W m^{-2}
R_{sr}	=	reflected shortwave solar radiation, W m^{-2}
R_a	=	longwave atmospheric radiation, W m^{-2}
R_{ar}	=	reflected longwave atmospheric radiation, W m^{-2}
R_b	=	back radiation, W m^{-2}
R_e	=	evaporative heat loss, W m^{-2}

For reference, the net rate can be closely approximated as

$$R_{net} = -KA(T - E) \qquad \text{Equation 3}$$

where

K	=	coefficient of surface heat exchange, W m^{-2} $°C^{-1}$
E	=	equilibrium temperature, C

This equation shows that if the water temperature exceeds equilibrium temperature, heat is lost from the water surface to the atmosphere; when the water temperature is less than equilibrium, heat is gained, and when the water temperature is equal to equilibrium, there is neither loss nor gain. Thus the equilibrium temperature is the temperature the water body approaches as steady meteorological conditions continue and can be computed once the coefficient of surface heat exchange is known.

There are several methods to compute K including an estimate based only on meteorological data independent of the water surface temperature. The linearized relationship is not as accurate as the term-by-term computation used in the response temperature model, because K is known to vary to some extent with the water surface temperature.

The two most important terms in the response temperature computation can be modified for calibration purposes. Shortwave solar radiation can be reduced to account for shading and the evaporative wind speed can be manipulated by adopting any one of several formulas to compute evaporative heat loss and by modifying the wind speed itself.

Further, groundwater inflows can be accounted for in the model as a simple calorimetric mix of groundwater with the computed response temperature.

7. Appendix 2 – Model Control File

Control file (W2_con.npt)

```
River Basin Model Version 3
INPUT PA      IMP     KMP     NRP     NBP
               14      13       1       1

TITLE C ..............................TITLE...................................
JR1     Run 727
        Weiss Lake
        Long term simulation 1991-2001
        one branch grid


TIME CON  TMSTRT   TMEND    YEAR
          1.5000  3927.0    1991

DLT CON      NDT  DLTMIN
               1 1.00000

DLT DATE    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD
         0.50000

DLT MAX   DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX
         3600.00

DLT FRN     DLTF    DLTF    DLTF    DLTF    DLTF    DLTF    DLTF    DLTF    DLTF
         0.80000
```

A value of 0.8 was found to allow for numerically stable simulations in all years with the final input time series.

```
DLT LIMI    VISC    CELC
              ON      ON

BRANCH G      US      DS     UHS     DHS      NL   SLOPE
BR1            2      13       0       0       1 0.00000
```

Given that the model layers are 2 m thick, NL was set to 1 rather than 2 or more that is commonly used.

```
LOCATION     LAT    LONG    EBOT      BS      BE    JBDN
JR1      34.2000 85.6000 151.830       1       1       0

INIT CND   TEMPI    ICEI  WTYPEC
JR1      5.00000 0.00000   FRESH

CALCULAT     VBC     EBC     MBC   PQINC     EVC     PRC
             OFF     OFF     OFF     OFF      ON     OFF
```

With the water balance implementation used in this application, it was appropriate to turn EVC ON.

```
INTERPOL   QINIC    TRIC   DTRIC    HDIC  QOUTIC    WDIC   METIC
              ON      ON     OFF     OFF      ON      ON      ON

DEAD SEA   WINDC    QINC   QOUTC   HEATC
              ON      ON      ON      ON

HEAT EXC   SLHTC
            TERM
```

```
RAD&EVAP     SROC     AFW     BFW     CFW   WINDH RH_EVAP  FETCHC
JR1            ON 9.20000 0.46000 2.00000 2.00000     OFF     OFF
```

Observed solar radiation was available, hence other values on this card can be ignored.

```
ICE COVE     ICEC  SLICEC  ALBEDO   HWICE    BICE    GICE  ICEMIN   ICET2
JR1           OFF  SIMPLE 0.25000 10.0000 0.60000 0.07000 0.05000 3.00000

TRANSPOR    SLTRC   THETA
           UPWIND 0.55000
```

UPWIND transport algorithm was chosen to avoid negative values that arose from undershoots in the other options that use second order algorithms.

```
WSC NUMB     NWSC
JR1             1

WSC DATE     WSCD    WSCD    WSCD    WSCD    WSCD    WSCD    WSCD    WSCD    WSCD
JR1       1.00000

WSC COEF      WSC     WSC     WSC     WSC     WSC     WSC     WSC     WSC     WSC
JR1       1.00000

HYD COEF       AX      DX    CBHE    TSED      FI TSEDFAC
JR1       1.00000 1.00000   7E-08 14.0000 0.01000 0.00000

AZ         AZFORM   AZMAX  AZCALC
JR1            W2 2.00000     IMP

FRICTION     TYPE
            CHEZY

N STRUC      NSTR
BR1             1

STR TOP     ESTRT   ESTRT   ESTRT   ESTRT   ESTRT   ESTRT   ESTRT   ESTRT   ESTRT
BR1             2

STR BOT     ESTRB   ESTRB   ESTRB   ESTRB   ESTRB   ESTRB   ESTRB   ESTRB   ESTRB
BR1            45

SINK TYP    SINKC   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC
BR1         POINT

E STRUC      ESTR    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR
BR1       162.500

W STRUC      WSTR    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR
BR1       0.00000

PIPES       NPIPE
                0

PIPE        IUSEG   IDSEG   INV-U   INV-D     DIA  LENGTH  FRIC_N  MIN_FR   WTHLC


PIPE-U     TRIBPL TRIBTOP TRIBBOT   KWTOP   KWBOT


PIPE-D     TRIBPL TRIBTOP TRIBBOT   KWTOP   KWBOT


NWEIR       NWEIR
                0

SPWEIR      IUSEG   IDSEG    ZSPW      A1      B1      A2      B2   WTHLC


SP-U       TRIBPL TRIBTOP TRIBBOT   KWTOP   KWBOT
```

```
SP-D      TRIBPL TRIBTOP TRIBBOT   KWTOP   KWBOT

SP-GAS    ON/OFF    EQN#    AGAS    BGAS    CGAS

NGATE      NGate
               0

GATE       IUSEG   IDSEG     ZGT     A1G     B1G     G1G     A2G     B2G     G2G
WTHLC

GATE WEI     GA1     GB1     GA2     GB2  DYNVAR

GT-U      TRIBPL TRIBTOP TRIBBOT   KWTOP   KWBOT

GT-D      TRIBPL TRIBTOP TRIBBOT   KWTOP   KWBOT

GT-GAS    ON/OFF    EQN#    AGAS    BGAS    CGAS

NWLC        NWLC
               0

WL CON1    IUSEG   IDSEG   ZPUMP   START     END    WLON   WLOFF    FLOW   WTHLC

WL CON2   TRIBPL TRIBTOP TRIBBOT   KWTOP   KWBOT

INT WEIR     NWR
               0

WEIR SEG     IWR     IWR     IWR     IWR     IWR     IWR     IWR     IWR     IWR

WEIR TOP    EWRT    EWRT    EWRT    EWRT    EWRT    EWRT    EWRT    EWRT    EWRT

WEIR BOT    EWRB    EWRB    EWRB    EWRB    EWRB    EWRB    EWRB    EWRB    EWRB

N WDRWAL     NWD
               1

W SEGMNT     IWD     IWD     IWD     IWD     IWD     IWD     IWD     IWD     IWD
              11

W EL         EWD     EWD     EWD     EWD     EWD     EWD     EWD     EWD     EWD
         164.500

W TOP       EWDT    EWDT    EWDT    EWDT    EWDT    EWDT    EWDT    EWDT    EWDT
               2

W BOT       EWDB    EWDB    EWDB    EWDB    EWDB    EWDB    EWDB    EWDB    EWDB
              45

PUMPBACK     JBG     KTG     KBG     JBP     KTP     KBP
               0       0       0       0       0       0

N TRIBS      NTR
               6
```

The six former branches were turned into tributaries.

```
TRIB PLA     PTRC     PTRC     PTRC     PTRC     PTRC     PTRC     PTRC     PTRC     PTRC
            DISTR    DISTR    DISTR    DISTR    DISTR    DISTR

TRIB SEG      ITR      ITR      ITR      ITR      ITR      ITR      ITR      ITR      ITR
                3        6        6        8        8        9

TRIB TOP     ETRT     ETRT     ETRT     ETRT     ETRT     ETRT     ETRT     ETRT     ETRT
                2        2        2        2        2        2

TRIB BOT     ETRB     ETRB     ETRB     ETRB     ETRB     ETRB     ETRB     ETRB     ETRB
               10       10       10       10       10       10

DST TRIB     DTRC     DTRC     DTRC     DTRC     DTRC     DTRC     DTRC     DTRC     DTRC
BR1            ON

PRINTER       LJC
               IV

HYD PRIN     HPRC     HPRC     HPRC     HPRC     HPRC     HPRC     HPRC     HPRC     HPRC
               ON       ON       ON       ON      OFF       ON      OFF      OFF      OFF
              OFF      OFF      OFF      OFF      OFF      OFF
```

Profile, snapshot and spreadsheet output was synchronized to the sample dates as well as time.

```
SNP PRIN     SNPC     NSNP    NISNP
JR1            ON      199       12

SNP DATE     SNPD     SNPD     SNPD     SNPD     SNPD     SNPD     SNPD     SNPD     SNPD
JR1       9.46000  71.4600  107.460  136.460  155.440  162.460  190.460  205.440  218.460
          234.450  253.460  267.450  281.460  295.420  311.460  346.460  491.500  535.470
          575.400  596.500  603.420  610.450  660.440  856.500  857.500  897.530  938.570
          953.460  961.500  962.500  988.430  1024.60  1220.50  1221.50  1260.42  1296.38
          1331.41  1346.50  1347.50  1358.48  1381.48  1634.54  1666.53  1701.44  1704.50
          1729.40  2004.48  2037.47  2061.45  2061.50  2075.45  2116.57  2299.50  2327.50
          2361.54  2362.50  2387.54  2397.50  2417.50  2418.56  2452.50  2479.61  2488.50
          2569.53  2576.46  2593.56  2597.45  2618.62  2619.31  2654.60  2681.63  2709.63
          2751.60  2752.46  2765.59  2774.60  2781.50  2788.54  2793.50  2808.63  2809.40
          2817.44  2843.60  2851.49  2863.55  2864.36  2892.57  2893.39  2928.59  2929.51
          3076.51  3109.47  3136.46  3145.50  3166.43  3199.45  3396.25  3396.29  3396.33
          3396.35  3396.43  3396.46  3396.51  3396.54  3396.57  3396.60  3432.28  3432.32
          3432.36  3432.39  3445.44  3466.53  3466.55  3466.59  3466.60  3466.63  3466.64
          3467.28  3467.33  3467.36  3467.39  3480.57  3495.28  3495.33  3495.37  3495.40
          3501.40  3528.53  3528.56  3528.59  3528.60  3528.64  3528.66  3529.27  3529.31
          3529.35  3529.37  3542.40  3558.28  3558.32  3558.36  3558.40  3563.41  3586.28
          3586.33  3586.36  3586.39  3768.75  3769.30  3769.34  3769.38  3769.40  3797.38
          3797.43  3797.48  3797.51  3797.61  3797.72  3797.76  3809.52  3831.58  3832.28
          3832.32  3832.37  3832.39  3832.41  3832.44  3846.40  3864.61  3865.31  3865.37
          3865.40  3865.44  3865.46  3865.51  3873.63  3894.63  3895.31  3895.35  3895.38
          3895.40  3895.42  3895.46  3906.44  3920.59  3921.30  3921.34  3921.38  3921.40
          3921.43  3921.48  3936.45  3956.77  3957.35  3957.38  3957.42  3957.44  3957.46
          3957.51

SNP FREQ     SNPF     SNPF     SNPF     SNPF     SNPF     SNPF     SNPF     SNPF     SNPF
JR1       1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00
          1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00
          1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00
          1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00
          1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00
          1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00
          1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00
          1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00
          1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00
          1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00
          1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00
          1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00
          1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00
          1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00  1000.00
```

```
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00

SNP SEG      ISNP    ISNP    ISNP    ISNP    ISNP    ISNP    ISNP    ISNP    ISNP
JR1             2       3       4       5       6       7       8       9      10
               11      12      13

SCR PRIN     SCRC    NSCR
JR1           OFF       1

SCR DATE     SCRD    SCRD    SCRD    SCRD    SCRD    SCRD    SCRD    SCRD    SCRD
JR1       1.00000

SCR FREQ     SCRF    SCRF    SCRF    SCRF    SCRF    SCRF    SCRF    SCRF    SCRF
JR1       1.00000

PRF PLOT     PRFC    NPRF   NIPRF
JR1            ON     199       2

PRF DATE     PRFD    PRFD    PRFD    PRFD    PRFD    PRFD    PRFD    PRFD    PRFD
JR1       9.46000 71.4600 107.460 136.460 155.440 162.460 190.460 205.440 218.460
          234.450 253.460 267.450 281.460 295.420 311.460 346.460 491.500 535.470
          575.400 596.500 603.420 610.450 660.440 856.500 857.500 897.530 938.570
          953.460 961.500 962.500 988.430 1024.60 1220.50 1221.50 1260.42 1296.38
          1331.41 1346.50 1347.50 1358.48 1381.48 1634.54 1666.53 1701.44 1704.50
          1729.40 2004.48 2037.47 2061.45 2061.50 2075.45 2116.57 2299.50 2327.50
          2361.54 2362.50 2387.54 2397.50 2417.50 2418.56 2452.50 2479.61 2488.50
          2569.53 2576.46 2593.56 2597.45 2618.62 2619.31 2654.60 2681.63 2709.63
          2751.60 2752.46 2765.59 2774.60 2781.50 2788.54 2793.50 2808.63 2809.40
          2817.44 2843.60 2851.49 2863.55 2864.36 2892.57 2893.39 2928.59 2929.51
          3076.51 3109.47 3136.46 3145.50 3166.43 3199.45 3396.25 3396.29 3396.33
          3396.35 3396.43 3396.46 3396.51 3396.54 3396.57 3396.60 3432.28 3432.32
          3432.36 3432.39 3445.44 3466.53 3466.55 3466.59 3466.60 3466.63 3466.64
          3467.28 3467.33 3467.36 3467.39 3480.57 3495.28 3495.33 3495.37 3495.40
          3501.40 3528.53 3528.56 3528.59 3528.60 3528.64 3528.66 3529.27 3529.31
          3529.35 3529.37 3542.40 3558.28 3558.32 3558.36 3558.40 3563.41 3586.28
          3586.33 3586.36 3586.39 3768.75 3769.30 3769.34 3769.38 3769.40 3797.38
          3797.43 3797.48 3797.51 3797.61 3797.72 3797.76 3809.52 3831.58 3832.28
          3832.32 3832.37 3832.39 3832.41 3832.44 3846.40 3864.61 3865.31 3865.37
          3865.40 3865.44 3865.46 3865.51 3873.63 3894.63 3895.31 3895.35 3895.38
          3895.40 3895.42 3895.46 3906.44 3920.59 3921.30 3921.34 3921.38 3921.40
          3921.43 3921.48 3936.45 3956.77 3957.35 3957.38 3957.42 3957.44 3957.46
          3957.51

PRF FREQ     PRFF    PRFF    PRFF    PRFF    PRFF    PRFF    PRFF    PRFF    PRFF
JR1       1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
```

```
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00

PRF SEG      IPRF    IPRF    IPRF    IPRF    IPRF    IPRF    IPRF    IPRF    IPRF
JR1             7      13

SPR PLOT     SPRC    NSPR   NISPR
JR1            ON     199       2

SPR DATE     SPRD    SPRD    SPRD    SPRD    SPRD    SPRD    SPRD    SPRD    SPRD
JR1       9.46000 71.4600 107.460 136.460 155.440 162.460 190.460 205.440 218.460
          234.450 253.460 267.450 281.460 295.420 311.460 346.460 491.500 535.470
          575.400 596.500 603.420 610.450 660.440 856.500 857.500 897.530 938.570
          953.460 961.500 962.500 988.430 1024.60 1220.50 1221.50 1260.42 1296.38
          1331.41 1346.50 1347.50 1358.48 1381.48 1634.54 1666.53 1701.44 1704.50
          1729.40 2004.48 2037.47 2061.45 2061.50 2075.45 2116.57 2299.50 2327.50
          2361.54 2362.50 2387.54 2397.50 2417.50 2418.56 2452.50 2479.61 2488.50
          2569.53 2576.46 2593.56 2597.45 2618.62 2619.31 2654.60 2681.63 2709.63
          2751.60 2752.46 2765.59 2774.60 2781.50 2788.54 2793.50 2808.63 2809.40
          2817.44 2843.60 2851.49 2863.55 2864.36 2892.57 2893.39 2928.59 2929.51
          3076.51 3109.47 3136.46 3145.50 3166.43 3199.45 3396.25 3396.29 3396.33
          3396.35 3396.43 3396.46 3396.51 3396.54 3396.57 3396.57 3432.28 3432.32
          3432.36 3432.39 3445.44 3466.53 3466.55 3466.59 3466.60 3466.63 3466.64
          3467.28 3467.33 3467.36 3467.39 3480.57 3495.28 3495.33 3495.37 3495.40
          3501.40 3528.53 3528.56 3528.59 3528.60 3528.64 3528.66 3529.27 3529.31
          3529.35 3529.37 3542.40 3558.28 3558.32 3558.36 3558.40 3563.41 3586.28
          3586.33 3586.36 3586.39 3768.75 3769.30 3769.34 3769.38 3769.40 3797.38
          3797.43 3797.48 3797.51 3797.61 3797.72 3797.76 3809.52 3831.58 3832.28
          3832.32 3832.37 3832.39 3832.41 3832.44 3846.40 3864.61 3865.31 3865.37
          3865.40 3865.44 3865.46 3865.51 3873.63 3894.63 3895.31 3895.35 3895.38
          3895.40 3895.42 3895.46 3906.44 3920.59 3921.30 3921.34 3921.38 3921.40
          3921.43 3921.48 3936.45 3956.77 3957.35 3957.38 3957.42 3957.44 3957.46
          3957.51

SPR FREQ     SPRF    SPRF    SPRF    SPRF    SPRF    SPRF    SPRF    SPRF    SPRF
JR1       1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
          1000.00

SPR SEG      ISPR    ISPR    ISPR    ISPR    ISPR    ISPR    ISPR    ISPR    ISPR
JR1             7      13

TSR PLOT     TSRC    NTSR
JR1            ON       1

TSR DATE     TSRD    TSRD    TSRD    TSRD    TSRD    TSRD    TSRD    TSRD    TSRD
JR1       1.50000

TSR FREQ     TSRF    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF
JR1       0.25000
```

```
KTTSR       KTTC    NKTT   NIKTT
              ON       3       2

KTTSR DA    KTTD    KTTD    KTTD    KTTD    KTTD    KTTD    KTTD    KTTD    KTTD
         1.50000 1000.00 4000.00

KTTSR FR    KTTF    KTTF    KTTF    KTTF    KTTF    KTTF    KTTF    KTTF    KTTF
         0.25000 0.25000 0.25000

KTTSR SE    IKTT    IKTT    IKTT    IKTT    IKTT    IKTT    IKTT    IKTT    IKTT
               7      13

WITH OUT    WDOC   NIWDO    WDOF
             OFF       2 0.50000

WITH SEG    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO
              28      30

VPL PLOT    VPLC    NVPL
JR1          OFF       1

VPL DATE    VPLD    VPLD    VPLD    VPLD    VPLD    VPLD    VPLD    VPLD    VPLD
JR1      1.50000

VPL FREQ    VPLF    VPLF    VPLF    VPLF    VPLF    VPLF    VPLF    VPLF    VPLF
JR1      1.00000

CPL PLOT    CPLC    NCPL
JR1          OFF       1

CPL DATE    CPLD    CPLD    CPLD    CPLD    CPLD    CPLD    CPLD    CPLD    CPLD
JR1      1.50000

CPL FREQ    CPLF    CPLF    CPLF    CPLF    CPLF    CPLF    CPLF    CPLF    CPLF
JR1      1.00000

FLUXES      FLXC    NFLX
JR1          OFF       1

FLX DATE    FLXD    FLXD    FLXD    FLXD    FLXD    FLXD    FLXD    FLXD    FLXD
JR1      1.50000

FLX FREQ    FLXF    FLXF    FLXF    FLXF    FLXF    FLXF    FLXF    FLXF    FLXF
JR1      30.0000

RESTART     RSOC    NRSO    RSIC
              ON       1     OFF

RSO DATE    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD
         1.00000

RSO FREQ    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF
         91.0000

CST COMP     CCC     PHC      KF
              ON     OFF       1

CST ACTI     CAC     CAC     CAC     CAC     CAC     CAC     CAC     CAC     CAC
             OFF      ON     OFF     OFF     OFF      ON     OFF     OFF     OFF
             OFF     OFF     OFF     OFF     OFF      ON      ON      ON     OFF
             OFF     OFF      ON      ON      ON      ON     OFF      ON      ON
              ON     OFF     OFF     OFF      ON     OFF     OFF

CST DERI     CDC     CDC     CDC     CDC     CDC     CDC     CDC     CDC     CDC
              ON      ON      ON      ON      ON      ON      ON      ON      ON
              ON      ON      ON      ON      ON      ON      ON      ON      ON
             OFF

CST FLUX     CFC     CFC     CFC     CFC     CFC     CFC     CFC     CFC     CFC
              ON      ON      ON      ON      ON      ON      ON      ON      ON
              ON      ON      ON      ON      ON      ON      ON      ON      ON
              ON      ON      ON      ON      ON      ON      ON      ON      ON
```

```
                 ON       ON       ON       ON       ON       ON       ON       ON       ON
                 ON       ON       ON       ON       ON       ON       ON       ON       ON
                 ON       ON       ON       ON       ON       ON       ON       ON       ON
                 ON       ON       ON       ON       ON       ON

CST ICON      C2I      C2I      C2I      C2I      C2I      C2I      C2I      C2I      C2I
JR1       1000.00 5.00000 0.00000 0.00000 5.00000 2.00000 4.50000 5.00000 8.00000
          0.10000 0.00000 0.70000 2.02200 0.10000 0.01000 0.10000 0.10000 1.00000
          0.05000 1.00000 0.10000 0.10000 0.10000 0.10000 0.00000 2.00000 2.00000
          2.00000 2.00000 2.00000 2.00000 8.00000 3.50000 5.00000

CST PRIN     CPRC     CPRC     CPRC     CPRC     CPRC     CPRC     CPRC     CPRC     CPRC
              OFF       ON      OFF      OFF      OFF       ON      OFF      OFF      OFF
              OFF      OFF      OFF      OFF      OFF       ON       ON       ON      OFF
              OFF      OFF       ON       ON       ON       ON      OFF       ON       ON
               ON      OFF      OFF      OFF       ON      OFF      OFF

CIN CON     CINAC    CINAC    CINAC    CINAC    CINAC    CINAC    CINAC    CINAC    CINAC
              OFF      OFF      OFF      OFF      OFF       ON      OFF      OFF      OFF
              OFF      OFF      OFF      OFF      OFF       ON       ON       ON      OFF
              OFF      OFF       ON      OFF      OFF      OFF      OFF       ON       ON
               ON      OFF      OFF      OFF       ON      OFF      OFF

CTR CON     CTRAC    CTRAC    CTRAC    CTRAC    CTRAC    CTRAC    CTRAC    CTRAC    CTRAC
              OFF      OFF      OFF      OFF      OFF       ON      OFF      OFF      OFF
              OFF      OFF      OFF      OFF      OFF       ON       ON       ON      OFF
              OFF      OFF       ON      OFF      OFF      OFF      OFF       ON       ON
               ON      OFF      OFF      OFF       ON      OFF      OFF

CDT CON     CDTAC    CDTAC    CDTAC    CDTAC    CDTAC    CDTAC    CDTAC    CDTAC    CDTAC
              OFF      OFF      OFF      OFF      OFF       ON      OFF      OFF      OFF
              OFF      OFF      OFF      OFF      OFF       ON       ON       ON      OFF
              OFF      OFF       ON      OFF      OFF      OFF      OFF       ON       ON
               ON      OFF      OFF      OFF       ON      OFF      OFF

CPR CON     CPRAC    CPRAC    CPRAC    CPRAC    CPRAC    CPRAC    CPRAC    CPRAC    CPRAC
              OFF      OFF      OFF      OFF      OFF      OFF      OFF      OFF      OFF
              OFF      OFF      OFF      OFF      OFF      OFF      OFF      OFF      OFF
              OFF      OFF      OFF      OFF      OFF      OFF      OFF      OFF      OFF
              OFF      OFF      OFF      OFF      OFF      OFF      OFF

EX COEF     EXH2O     EXSS     EXOM     BETA
JR1       0.25000 0.10000 0.10000 0.45000
```

Default values were used, except the modification that the effect of algal shading, suspended solids, and organic matter was considered identical in the first approximation.

```
ALG EX        EXA      EXA      EXA      EXA      EXA      EXA
          0.10000 0.10000 0.10000 0.10000 0.10000 0.10000

COLIFORM   COLQ10    COLDK
JR1       1.04000 1.40000

C_ARBIT C_ARBQ10 C_ARBDK  C_ARBS
JR1       1.04000 0.25000 0.50000

S SOLIDS      SS1      SS2      SS3      SS4      SS5      SS6      SS7      SS8      SS9
          0.20000 1.00000 0.50000 0.10000 0.05000 0.01000 0.00500 0.00100 0.00010
```

Only one SS fraction was modeled. A value of 0.2 per day was arrived at through calibration, keeping in mind the associated loss of P associated with inorganic particulate settling. Field data did not support modeling more than one SS fraction.

```
ALGAL RA       AG       AR       AE       AM       AS     AHSP     AHSN    AHSSI     ASAT
ALG1      2.27000 0.04000 0.10000 0.05000 0.20000 0.00300 0.01400 0.00000 50.0000
ALG2      1.90000 0.03000 0.02000 0.05000 0.10000 0.00500 0.02000 0.00000 75.0000
ALG3      0.60000 0.04000 0.02000 0.01000 0.05000 0.02000 0.00100 0.00000 150.000
ALG4      0.80000 0.02000 0.02000 0.01000 0.05000 0.00300 0.01200 0.00000 75.0000
ALG5      0.80000 0.02000 0.02000 0.01000 0.15000 0.00900 0.01500 0.00000 75.0000
```

ALG6	3.50000	0.02000	0.02000	0.01000	0.01000	0.00300	0.01000	0.00000	75.0000

ALGAL TE	AT1	AT2	AT3	AT4	AK1	AK2	AK3	AK4
ALG1	5.00000	15.0000	20.0000	25.0000	0.10000	0.99000	0.99000	0.1000
ALG2	10.0000	20.0000	30.0000	45.0000	0.10000	0.99000	0.99000	0.1000
ALG3	15.0000	25.0000	30.0000	45.0000	0.10000	0.99000	0.99000	0.1000
ALG4	10.0000	35.0000	40.0000	50.0000	0.10000	0.99000	0.99000	0.01000
ALG5	10.0000	20.0000	25.0000	30.0000	0.10000	0.99000	0.99000	0.01000
ALG6	15.0000	20.0000	22.0000	25.0000	0.10000	0.99000	0.99000	0.01000

Algal rates and temperature dependence were arrived at through extensive calibration experiments.

ALG STOI	ALGP	ALGN	ALGC	ALGSI	ACHLA
ALG1	0.01000	0.08000	0.45000	0.00000	120.0
ALG2	0.01000	0.08000	0.45000	0.00000	90.0
ALG3	0.01000	0.08000	0.45000	0.00000	45.0
ALG4	0.00500	0.08000	0.45000	0.00000	65.0000
ALG5	0.00500	0.08000	0.45000	0.00000	65.0000
ALG6	0.00500	0.08000	0.45000	0.00000	65.0000

Algal nutrient stoichiometry was assumed from inspection of literature values and default recommended values, and not changed during calibration. ACHLA values were a compromise between literature values and the CE-QUAL-W2 manual recommendation of a single value for all algal groups.

DOM	LDOMDK	RDOMDK	LRDDK
JR1	0.12000	0.02000	0.01000

POM	LPOMDK	RPOMDK	LRPDK	POMS	APOM
JR1	0.06000	0.01000	0.00100	0.20000	0.80000

OM STOIC	ORGP	ORGN	ORGC	ORGSI
JR1	0.02000	0.11000	0.45000	0.18000

All of the above organic matter parameters were adjusted during calibration, except for ORGC. ORGSI was not relevant as silica was not modeled.

OM RATE	OMT1	OMT2	OMK1	OMK2
JR1	4.00000	30.0000	0.10000	0.99000

CBOD	KBOD	TBOD	RBOD
JR1	0.25000	1.01470	1.85000

PHOSPHOR	PO4R	PARTP
JR1	0.00000	0.90000

Based on flux measurements, PO4R was set to zero. PARTP was arrived at through calibration.

AMMONIUM	NH4R	NH4DK
JR1	0.01000	0.80000

NH4R was set to a small value. NH4DK was arrived at through calibration.

NH4 RATE	NH4T1	NH4T2	NH4K1	NH4K2
JR1	5.00000	25.0000	0.10000	0.99000

NITRATE	NO3DK
JR1	0.05000

NO3 RATE	NO3T1	NO3T2	NO3K1	NO3K2
JR1	5.00000	25.0000	0.10000	0.99000

All of the above nitrogen parameters were adjusted during calibration, except for ORGC. ORGSI was not relevant as silica was not modeled.

```
SILICA       DSIR    PSIS   PSIDK  PARTSI
JR1      0.10000 0.00000 0.30000 0.20000

IRON          FER     FES
JR1      0.10000 0.00000

SED CO2      CO2R
JR1      0.10000

STOICHMT   O2NH4    O2OM    O2AR    O2AG
JR1      4.57000 1.40000 1.10000 1.40000

O2 LIMIT   O2LIM
         1.00000

SEDIMENT    SEDC   PRNSC   SEDCI     SDK    FSOD
JR1           ON      ON 0.00000 0.00000 1.00000

SOD RATE   SODT1   SODT2   SODK1   SODK2
JR1      4.00000 30.0000 0.10000 0.99000

SHIFT DE     SDC
JR1          OFF

S DEMAND     SOD     SOD     SOD     SOD     SOD     SOD     SOD     SOD     SOD
         3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000
         3.00000 3.00000 3.00000 3.00000 3.00000
```

SOD was assigned a constant value at all segments for simplicity. Note that SOD actually exerted is dependent on water temperature, and is thus seasonally variable.

```
REAERATI    TYPE    EQN#   COEF1   COEF2   COEF3   COEF4
JR1         LAKE       5 0.00000 0.00000 0.00000 0.00000

RSI FILE..................................RSIFN.................................
        initialize.npt
```

This file is

```
QWD FILE..................................QWDFN.................................
        qwd hourly.npt

BTH FILE..................................BTHFN.................................
JR1     bth_wq1br.npt

MET FILE..................................METFN.................................
JR1     met.npt

VPR FILE..................................VPRFN.................................
JR1     vpr.npt

LPR FILE..................................LPRFN.................................
JR1     lpr.npt

QIN FILE..................................QINFN.................................
BR1     qin_br1.csv

TIN FILE..................................TINFN.................................
BR1     tin_coosa.npt

CIN FILE..................................CINFN.................................
BR1     coosa final cin.prn

QOT FILE..................................QOTFN.................................
BR1     qot hourly.npt

QGT FILE..................................QGTFN.................................
        qgate.npt
```

```
QTR FILE.................................QTRFN................................
TR1     qin_br2.csv
TR2     qin_br3.csv
TR3     qin_br4.csv
TR4     qin_br5.csv
TR5     qin_br6.csv
TR6     qin_br7.csv

TTR FILE.................................TTRFN................................
TR1     tin_br2.npt
TR2     tin_br3.npt
TR3     tin_br4.npt
TR4     tin_br5.npt
TR5     tin_br6.npt
TR6     tin_br7.npt

CTR FILE.................................CTRFN................................
TR1     cin_br2.npt
TR2     cin_br3.npt
TR3     cin_br4.npt
TR4     cin_br5.npt
TR5     cin_br6.npt
TR6     cin_br7.npt
```

Inflow, temperature and concentration files were not renamed though former branches were interpreted as tributaries in the simplified one branch grid.

```
QDT FILE.................................QDTFN................................
BR1     qdt_br1.csv

TDT FILE.................................TDTFN................................
BR1     tdt_br1.npt

CDT FILE.................................CDTFN................................
BR1     cdt_br1.npt

PRE FILE.................................PREFN................................
BR1     pre_br1.npt - not used

TPR FILE.................................TPRFN................................
BR1     tpr_br1.npt - not used

CPR FILE.................................CPRFN................................
BR1     cpr_br1.npt - not used

EUH FILE.................................EUHFN................................
BR1

TUH FILE.................................TUHFN................................
BR1

CUH FILE.................................CUHFN................................
BR1

EDH FILE.................................EDHFN................................
BR1

TDH FILE.................................TDHFN................................
BR1

CDH FILE.................................CDHFN................................
BR1

SNP FILE.................................SNPFN................................
JR1     snp.opt

TSR FILE.................................TSRFN................................
```

```
JR1     tsr.opt

PRF FILE.................................PRFFN.................................
JR1     prf.opt

TKT FILE.................................TKTFN.................................
        tsrkt.dat

VPL FILE.................................VPLFN.................................
JR1     vpl.opt

CPL FILE.................................CPLFN.................................
JR1     cpl.opt

SPR FILE.................................SPRFN.................................
JR1     spr.csv

FLX FILE.................................FLXFN.................................
JR1     kfl.opt

WSF FILE.................................WSFFN.................................
JR1     wsf.opt
```

8. Appendix 3 –Temperature and dissolved oxygen profile comparisons

Units of the three residual statistics are mg/l for DO and degrees Centigrade for temperature comparisons.

Time	Segment	Constituent	Obs count	Model count	Compared Count	ME	AME	RMS
5/5/92 12:00 PM	RWQMP-WEISS2	DO (WRDB)	9	7	8	-2.00	2.00	2.25
5/5/92 12:00 PM	RWQMP-WEISS1	DO (WRDB)	7	6	6	-2.82	2.82	3.16
5/5/92 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	7	6	6	0.16	0.43	0.50
5/5/92 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	9	7	8	0.90	0.90	1.01
6/18/92 10:45 AM	COFWE588.6	DO (APC)	7	6	5	-5.41	5.41	5.74
6/18/92 10:45 AM	COFWE588.6	TEMP (APC)	7	6	5	2.47	2.47	2.63
7/28/92 9:30 AM	COFWE588.6	DO (APC)	7	6	5	-1.17	1.29	1.70
7/28/92 9:30 AM	COFWE588.6	TEMP (APC)	7	6	5	-0.01	0.24	0.25
8/18/92 12:00 PM	RWQMP-WEISS1	DO (WRDB)	9	6	8	-0.77	0.79	0.91
8/18/92 12:00 PM	RWQMP-WEISS2	DO (WRDB)	14	7	12	-1.87	2.03	2.17
8/18/92 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	9	6	8	-0.41	0.41	0.42
8/18/92 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	14	7	12	0.53	0.53	0.64
8/25/92 9:50 AM	COFWE588.6	DO (APC)	7	6	6	-0.52	0.85	1.03
8/25/92 9:50 AM	COFWE588.6	TEMP (APC)	7	6	6	-0.12	0.29	0.32
9/1/92 10:20 AM	COFWE588.6	DO (APC)	7	6	6	-0.90	1.12	1.52
9/1/92 10:20 AM	COFWE588.6	TEMP (APC)	7	6	6	0.09	0.13	0.16
10/21/92 10:05 AM	COFWE588.6	DO (APC)	7	6	6	-0.76	0.76	0.80
10/21/92 10:05 AM	COFWE588.6	TEMP (APC)	7	6	6	-1.10	1.10	1.10
5/5/93 12:00 PM	RWQMP-WEISS1	DO (WRDB)	8	6	5	-0.98	0.98	1.15
5/5/93 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	8	6	5	-0.10	0.36	0.43
5/6/93 12:00 PM	RWQMP-WEISS2	DO (WRDB)	7	7	6	-1.81	2.11	2.61
5/6/93 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	7	7	6	0.57	1.40	1.59
6/15/93 12:16 PM	COFWE588.6	DO (APC)	7	6	5	-3.47	3.47	3.70
6/15/93 12:16 PM	COFWE588.6	TEMP (APC)	7	6	5	0.43	0.68	0.75
7/26/93 1:55 PM	COFWE588.6	DO (APC)	4	6	3	-2.32	2.32	2.65
7/26/93 1:55 PM	COFWE588.6	TEMP (APC)	4	6	3	0.22	0.22	0.27
8/10/93 10:58 AM	COFWE588.6	DO (APC)	10	6	6	-2.28	2.28	2.37
8/10/93 10:58 AM	COFWE588.6	TEMP (APC)	10	6	6	-0.36	0.36	0.37
8/18/93 12:00 PM	RWQMP-WEISS1	DO (WRDB)	12	6	10	-0.41	0.75	0.84
8/18/93 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	12	6	10	-0.44	0.58	0.65
8/19/93 12:00 PM	RWQMP-WEISS2	DO (WRDB)	12	7	11	-1.63	1.63	1.97
8/19/93 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	12	7	11	-0.76	0.79	0.89
9/14/93 9:46 AM	COFWE588.6	DO (APC)	9	6	6	-0.86	1.32	1.35
9/14/93 9:46 AM	COFWE588.6	TEMP (APC)	9	6	6	-0.54	0.54	0.54
10/20/93 1:55 PM	COFWE588.6	DO (APC)	8	6	6	-0.49	0.50	0.86
10/20/93 1:55 PM	COFWE588.6	TEMP (APC)	8	6	6	-1.48	1.48	1.50
5/4/94 12:00 PM	RWQMP-WEISS1	DO (WRDB)	9	6	8	-1.81	1.81	1.89
5/4/94 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	9	6	8	1.03	1.03	1.08

Time	Segment	Constituent	Obs count	Model count	Compared Count	ME	AME	RMS
5/5/94 12:00 PM	RWQMP-WEISS2	DO (WRDB)	10	7	9	-2.92	2.92	3.07
5/5/94 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	10	7	9	0.96	0.96	0.99
6/13/94 9:30 AM	COFWE588.6	DO (APC)	9	6	5	-1.70	1.70	2.02
6/13/94 9:30 AM	COFWE588.6	TEMP (APC)	9	6	5	0.85	0.85	1.13
7/19/94 9:35 AM	COFWE588.6	DO (APC)	8	6	5	-3.52	3.52	3.64
7/19/94 9:35 AM	COFWE588.6	TEMP (APC)	8	6	5	0.84	0.84	0.97
8/23/94 10:45 AM	COFWE588.6	DO (APC)	8	6	5	-0.31	1.37	1.57
8/23/94 10:45 AM	COFWE588.6	TEMP (APC)	8	6	5	-0.50	0.52	0.97
9/7/94 12:00 PM	RWQMP-WEISS1	DO (WRDB)	10	6	9	0.61	1.08	1.45
9/7/94 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	10	6	9	-0.77	0.77	0.77
9/8/94 12:00 PM	RWQMP-WEISS2	DO (WRDB)	10	7	9	0.10	0.55	0.64
9/8/94 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	10	7	9	-0.49	0.49	0.49
9/19/94 10:38 AM	COFWE588.6	DO (APC)	8	6	6	-2.20	2.20	2.93
9/19/94 10:38 AM	COFWE588.6	TEMP (APC)	8	6	6	-0.47	0.47	0.50
6/22/95 12:40 PM	COFWE588.6	DO (APC)	8	6	6	-1.00	1.00	1.13
6/22/95 12:40 PM	COFWE588.6	TEMP (APC)	8	6	6	-0.67	0.67	0.69
7/24/95 1:30 PM	COFWE588.6	DO (APC)	8	6	7	-2.25	2.25	2.52
7/24/95 1:30 PM	COFWE588.6	TEMP (APC)	8	6	7	-0.59	0.59	0.60
8/31/95 12:00 PM	RWQMP-WEISS2	DO (WRDB)	14	7	13	-0.24	0.81	1.43
8/31/95 12:00 PM	RWQMP-WEISS1	DO (WRDB)	13	6	12	-0.09	1.22	1.54
8/31/95 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	13	6	12	-0.89	0.89	0.90
8/31/95 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	14	7	13	-1.08	1.08	1.12
9/25/95 9:35 AM	COFWE588.6	DO (APC)	8	6	5	-0.46	0.46	0.49
9/25/95 9:35 AM	COFWE588.6	TEMP (APC)	8	6	5	-0.95	0.95	0.95
6/26/96 10:55 AM	COFWE588.6	DO (APC)	7	6	5	-1.77	1.95	2.53
6/26/96 10:55 AM	COFWE588.6	TEMP (APC)	7	6	5	-0.44	1.10	1.25
7/29/96 10:50 AM	COFWE588.6	DO (APC)	7	6	6	0.57	0.61	0.65
7/29/96 10:50 AM	COFWE588.6	TEMP (APC)	7	6	6	-0.37	0.37	0.39
8/22/96 10:18 AM	COFWE588.6	DO (APC)	9	12	6	-1.66	1.66	1.99
8/22/96 10:18 AM	COFWE588.6	TEMP (APC)	9	12	6	-1.33	1.33	1.36
8/22/96 12:00 PM	RWQMP-WEISS2	DO (WRDB)	14	14	13	-1.06	1.19	1.43
8/22/96 12:00 PM	RWQMP-WEISS1	DO (WRDB)	14	12	11	-1.64	1.80	2.31
8/22/96 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	14	14	13	-0.81	0.81	0.86
8/22/96 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	14	12	11	-1.40	1.40	1.44
9/5/96 10:12 AM	COFWE588.6	DO (APC)	10	6	5	-0.52	0.52	0.52
9/5/96 10:12 AM	COFWE588.6	TEMP (APC)	10	6	5	-1.33	1.33	1.36
10/16/96 1:35 PM	COFWE588.6	DO (APC)	8	6	6	-0.88	0.88	1.06
10/16/96 1:35 PM	COFWE588.6	TEMP (APC)	8	6	6	-2.83	2.83	2.83
4/17/97 12:00 PM	RWQMP-WEISS1	DO (WRDB)	14	6	13	-3.80	3.80	3.86
4/17/97 12:00 PM	RWQMP-WEISS2	DO (WRDB)	14	7	13	-4.15	4.15	4.17
4/17/97 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	14	7	13	-0.02	0.32	0.39
4/17/97 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	14	6	13	-0.63	0.68	0.75
5/15/97 12:00 PM	RWQMP-WEISS2	DO (WRDB)	14	7	13	-3.21	3.21	3.23
5/15/97 12:00 PM	RWQMP-WEISS1	DO (WRDB)	13	6	12	-3.38	3.38	3.52

Time	Segment	Constituent	Obs count	Model count	Compared Count	ME	AME	RMS
5/15/97 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	13	6	12	0.13	0.41	0.52
5/15/97 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	14	7	13	0.50	0.50	0.65
6/18/97 1:30 PM	COFWE588.6	DO (APC)	7	6	5	-3.33	3.33	3.37
6/18/97 1:30 PM	COFWE588.6	TEMP (APC)	7	6	5	0.46	0.59	0.70
6/19/97 12:00 PM	RWQMP-WEISS2	DO (WRDB)	14	7	13	-1.57	1.57	1.64
6/19/97 12:00 PM	RWQMP-WEISS1	DO (WRDB)	13	6	12	-3.00	3.00	3.15
6/19/97 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	14	7	13	-0.06	0.43	0.51
6/19/97 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	13	6	12	0.14	0.50	0.61
7/14/97 11:30 AM	COFWE588.6	DO (APC)	7	6	5	0.05	1.30	1.46
7/14/97 11:30 AM	COFWE588.6	TEMP (APC)	7	6	5	0.15	0.27	0.32
7/24/97 12:00 PM	RWQMP-WEISS1	DO (WRDB)	14	6	11	-1.83	1.88	2.24
7/24/97 12:00 PM	RWQMP-WEISS2	DO (WRDB)	14	7	13	-3.56	3.56	4.01
7/24/97 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	14	6	11	0.01	0.08	0.09
7/24/97 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	14	7	13	-0.29	0.36	0.45
8/13/97 12:00 PM	RWQMP-WEISS1	DO (WRDB)	14	6	11	-0.65	0.73	0.86
8/13/97 12:00 PM	RWQMP-WEISS2	DO (WRDB)	14	7	13	-3.04	3.04	3.64
8/13/97 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	14	6	11	-0.44	0.58	0.61
8/13/97 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	14	7	13	-0.44	0.68	0.86
8/14/97 12:35 PM	COFWE588.6	DO (APC)	7	6	6	-1.15	1.22	1.54
8/14/97 12:35 PM	COFWE588.6	TEMP (APC)	7	6	6	-0.20	0.50	0.54
9/17/97 12:00 PM	RWQMP-WEISS2	DO (WRDB)	13	7	12	0.63	0.76	0.85
9/17/97 12:00 PM	RWQMP-WEISS1	DO (WRDB)	13	6	12	-0.65	0.89	1.12
9/17/97 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	13	6	12	-1.90	1.90	1.91
9/17/97 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	13	7	12	-2.01	2.01	2.02
10/14/97 2:00 PM	COFWE588.6	DO (APC)	7	6	6	-1.50	1.61	2.73
10/14/97 2:00 PM	COFWE588.6	TEMP (APC)	7	6	6	-1.70	1.70	1.70
10/23/97 12:00 PM	RWQMP-WEISS2	DO (WRDB)	13	7	12	-0.13	0.21	0.23
10/23/97 12:00 PM	RWQMP-WEISS1	DO (WRDB)	13	6	12	-0.24	0.25	0.28
10/23/97 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	13	6	12	-2.27	2.27	2.28
10/23/97 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	13	7	12	-2.50	2.50	2.52
1/12/98 2:00 PM	CORWE604.2	DO (APC)	9	6	6	-2.29	2.29	2.29
1/12/98 2:00 PM	CORWE604.2	TEMP (APC)	9	6	6	-1.95	1.95	1.95
1/19/98 12:10 PM	COFWE588.6	DO (APC)	8	5	5	-1.64	1.64	1.65
1/19/98 12:10 PM	COFWE588.6	TEMP (APC)	8	5	5	-2.61	2.61	2.61
2/5/98 4:20 PM	COFWE588.6	DO (APC)	9	6	6	-2.58	2.58	2.58
2/5/98 4:20 PM	COFWE588.6	TEMP (APC)	9	6	6	-1.41	1.41	1.41
3/3/98 7:26 AM	COFWE588.6	DO (APC)	9	5	6	-2.40	2.40	2.40
3/3/98 7:26 AM	COFWE588.6	TEMP (APC)	9	5	6	-0.15	0.15	0.15
4/7/98 4:30 PM	COFWE588.6	DO (APC)	9	6	7	-2.70	2.70	2.73
4/7/98 4:30 PM	COFWE588.6	TEMP (APC)	9	6	7	-0.21	0.55	0.58
5/4/98 4:12 PM	COFWE588.6	DO (APC)	9	6	6	-3.41	3.41	3.44
5/4/98 4:12 PM	COFWE588.6	TEMP (APC)	9	6	6	-0.01	0.20	0.26
6/1/98 4:30 PM	COFWE588.6	DO (APC)	10	6	6	-2.69	2.69	2.88
6/1/98 4:30 PM	COFWE588.6	TEMP (APC)	10	6	6	0.35	0.58	0.77

Time	Segment	Constituent	Obs count	Model count	Compared Count	ME	AME	RMS
7/14/98 11:18 AM	COFWE588.6	DO (APC)	9	6	6	0.04	0.10	0.11
7/14/98 11:18 AM	COFWE588.6	TEMP (APC)	9	6	6	0.67	0.67	0.67
7/27/98 3:45 PM	COFWE588.6	DO (APC)	8	6	6	-1.30	1.49	1.85
7/27/98 3:45 PM	COFWE588.6	TEMP (APC)	8	6	6	0.93	0.93	0.93
8/5/98 4:20 PM	COFWE588.6	DO (APC)	9	6	6	-0.51	1.31	1.68
8/5/98 4:20 PM	COFWE588.6	TEMP (APC)	9	6	6	0.17	0.35	0.36
8/12/98 12:00 PM	RWQMP-WEISS2	DO (WRDB)	12	7	11	0.03	0.19	0.23
8/12/98 12:00 PM	RWQMP-WEISS1	DO (WRDB)	16	6	13	0.71	0.71	0.78
8/12/98 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	14	6	11	-0.27	0.27	0.28
8/12/98 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	12	7	11	-0.57	0.57	0.57
8/19/98 11:25 AM	COFWE588.6	DO (APC)	7	6	5	-1.56	1.56	1.62
8/19/98 11:25 AM	COFWE588.6	TEMP (APC)	7	6	5	-0.16	0.44	0.50
9/9/98 9:13 AM	COFWE588.6	DO (APC)	9	6	7	-0.66	0.66	0.66
9/9/98 9:13 AM	COFWE588.6	TEMP (APC)	9	6	7	-0.48	0.48	0.51
9/17/98 1:30 PM	COFWE588.6	DO (APC)	8	6	7	-1.93	2.06	2.59
9/17/98 1:30 PM	COFWE588.6	TEMP (APC)	8	6	7	-1.18	1.18	1.38
10/13/98 4:05 PM	COFWE588.6	DO (APC)	9	6	7	-1.09	2.13	2.62
10/13/98 4:05 PM	COFWE588.6	TEMP (APC)	9	6	7	-0.62	0.62	0.82
10/21/98 1:40 PM	COFWE588.6	DO (APC)	8	6	7	-1.88	1.88	1.94
10/21/98 1:40 PM	COFWE588.6	TEMP (APC)	8	6	7	-1.07	1.07	1.09
11/3/98 8:28 AM	COFWE588.6	DO (APC)	9	6	7	-1.54	1.54	1.81
11/3/98 8:28 AM	COFWE588.6	TEMP (APC)	9	6	7	-2.26	2.26	2.27
12/2/98 9:17 AM	COFWE588.6	DO (APC)	8	5	5	-0.66	0.66	0.74
12/2/98 9:17 AM	COFWE588.6	TEMP (APC)	8	5	5	-2.83	2.83	2.83
1/7/99 1:25 PM	COFWE588.6	DO (APC)	9	5	6	0.45	0.45	0.46
1/7/99 1:25 PM	COFWE588.6	TEMP (APC)	9	5	6	-1.57	1.57	1.59
6/3/99 10:45 AM	COFWE588.6	DO (APC)	9	6	6	-1.05	2.01	2.19
6/3/99 10:45 AM	COFWE588.6	TEMP (APC)	9	6	6	0.06	0.52	0.58
7/6/99 10:40 AM	COFWE588.6	DO (APC)	9	6	6	-2.24	2.24	2.34
7/6/99 10:40 AM	COFWE588.6	TEMP (APC)	9	6	6	0.17	0.44	0.66
8/2/99 10:40 AM	COFWE588.6	DO (APC)	9	6	7	-1.72	1.72	2.01
8/2/99 10:40 AM	COFWE588.6	TEMP (APC)	9	6	7	0.43	0.54	0.67
8/11/99 12:00 PM	RWQMP-WEISS2	DO (WRDB)	13	7	12	-0.79	0.92	1.44
8/11/99 12:00 PM	RWQMP-WEISS1	DO (WRDB)	12	6	11	1.57	1.84	2.35
8/11/99 12:00 PM	RWQMP-WEISS2	TEMP (WRDB)	13	7	12	-0.44	0.44	0.51
8/11/99 12:00 PM	RWQMP-WEISS1	TEMP (WRDB)	12	6	11	0.41	0.45	0.62
9/1/99 10:00 AM	COFWE588.6	DO (APC)	9	6	7	1.32	1.34	1.71
9/1/99 10:00 AM	COFWE588.6	TEMP (APC)	9	6	7	0.08	0.09	0.13
10/4/99 10:27 AM	COFWE588.6	DO (APC)	8	5	5	-1.60	1.60	1.70
10/4/99 10:27 AM	COFWE588.6	TEMP (APC)	8	5	5	-0.94	0.94	0.94
4/18/00 6:05 AM	RWQMP-WEISS1	DO (WRDB)	14	24	11	-1.82	1.82	1.95
4/18/00 6:05 AM	RWQMP-WEISS1	TEMP (WRDB)	14	24	11	-0.35	0.39	0.56
4/18/00 7:04 AM	RWQMP-WEISS2	DO (WRDB)	12	28	11	-2.12	2.12	2.26
4/18/00 7:04 AM	RWQMP-WEISS2	TEMP (WRDB)	12	28	11	0.00	0.41	0.47

Time	Segment	Constituent	Obs count	Model count	Compared Count	ME	AME	RMS
5/24/00 6:48 AM	RWQMP-WEISS1	DO (WRDB)	12	24	11	-0.09	0.92	1.18
5/24/00 6:48 AM	RWQMP-WEISS1	TEMP (WRDB)	12	24	11	0.73	0.73	0.75
5/24/00 7:47 AM	RWQMP-WEISS2	DO (WRDB)	12	28	11	-3.00	3.00	3.42
5/24/00 7:47 AM	RWQMP-WEISS2	TEMP (WRDB)	12	28	11	-0.21	0.21	0.27
6/6/00 10:00 AM	COFWE588.6	DO (APC)	9	6	7	-2.22	2.43	3.56
6/6/00 10:00 AM	COFWE588.6	TEMP (APC)	9	6	7	0.58	0.58	0.59
6/28/00 6:48 AM	RWQMP-WEISS1	DO (WRDB)	13	24	12	0.32	1.02	1.48
6/28/00 6:48 AM	RWQMP-WEISS1	TEMP (WRDB)	13	24	12	0.69	0.69	0.76
6/28/00 7:51 AM	RWQMP-WEISS2	DO (WRDB)	14	28	13	-2.20	2.20	2.61
6/28/00 7:51 AM	RWQMP-WEISS2	TEMP (WRDB)	14	28	13	-0.37	0.51	0.52
7/11/00 1:07 PM	COFWE588.6	DO (APC)	9	6	7	-1.84	2.14	2.84
7/11/00 1:07 PM	COFWE588.6	TEMP (APC)	9	6	7	-0.07	0.20	0.23
7/26/00 6:49 AM	RWQMP-WEISS1	DO (WRDB)	14	24	13	-0.38	1.13	1.58
7/26/00 6:49 AM	RWQMP-WEISS1	TEMP (WRDB)	13	24	12	0.59	0.59	0.59
7/26/00 7:54 AM	RWQMP-WEISS2	DO (WRDB)	13	28	12	-0.53	0.56	0.62
7/26/00 7:54 AM	RWQMP-WEISS2	TEMP (WRDB)	13	28	12	0.73	0.73	0.74
8/1/00 9:06 AM	COFWE588.6	DO (APC)	8	6	6	2.04	2.04	2.05
8/1/00 9:06 AM	COFWE588.6	TEMP (APC)	8	6	6	0.06	0.06	0.06
8/29/00 6:25 AM	RWQMP-WEISS1	DO (WRDB)	13	24	12	1.11	1.21	1.79
8/29/00 6:25 AM	RWQMP-WEISS1	TEMP (WRDB)	13	24	12	-0.06	0.17	0.20
8/29/00 7:32 AM	RWQMP-WEISS2	DO (WRDB)	13	28	12	0.60	0.75	1.06
8/29/00 7:32 AM	RWQMP-WEISS2	TEMP (WRDB)	13	28	12	-0.64	0.64	0.66
9/11/00 8:42 AM	COFWE588.6	DO (APC)	9	6	7	-1.50	1.50	2.16
9/11/00 8:42 AM	COFWE588.6	TEMP (APC)	9	6	7	0.10	0.24	0.26
9/27/00 6:46 AM	RWQMP-WEISS1	DO (WRDB)	12	24	11	-0.64	0.72	0.74
9/27/00 6:46 AM	RWQMP-WEISS1	TEMP (WRDB)	12	24	11	-0.25	0.25	0.27
9/27/00 7:43 AM	RWQMP-WEISS2	DO (WRDB)	13	28	12	-0.25	0.25	0.26
9/27/00 7:43 AM	RWQMP-WEISS2	TEMP (WRDB)	13	28	12	0.39	0.39	0.39
10/2/00 9:21 AM	COFWE588.6	DO (APC)	8	6	6	-1.92	1.92	2.14
10/2/00 9:21 AM	COFWE588.6	TEMP (APC)	8	6	6	-0.97	0.97	1.07
10/25/00 6:37 AM	RWQMP-WEISS1	DO (WRDB)	11	20	8	-1.62	1.62	1.73
10/25/00 6:37 AM	RWQMP-WEISS1	TEMP (WRDB)	11	20	8	-2.05	2.05	2.07
10/25/00 7:54 AM	RWQMP-WEISS2	DO (WRDB)	13	24	10	-0.67	0.84	1.30
10/25/00 7:54 AM	RWQMP-WEISS2	TEMP (WRDB)	13	24	10	-2.63	2.63	2.66
4/26/01 7:19 AM	RWQMP-WEISS1	DO (WRDB)	13	24	10	-2.71	2.71	3.07
4/26/01 7:19 AM	RWQMP-WEISS1	TEMP (WRDB)	13	24	10	0.77	0.77	0.85
4/26/01 8:14 AM	RWQMP-WEISS2	DO (WRDB)	13	28	10	-4.42	4.42	4.67
4/26/01 8:14 AM	RWQMP-WEISS2	TEMP (WRDB)	13	28	10	0.93	0.98	1.13
5/24/01 9:07 AM	RWQMP-WEISS1	DO (WRDB)	13	18	10	-0.16	0.91	0.98
5/24/01 9:07 AM	RWQMP-WEISS1	TEMP (WRDB)	13	18	10	0.60	0.60	0.63
5/24/01 10:21 AM	RWQMP-WEISS2	DO (WRDB)	13	28	10	-1.02	1.49	1.53
5/24/01 10:21 AM	RWQMP-WEISS2	TEMP (WRDB)	13	28	10	0.00	0.06	0.07
6/5/01 11:45 AM	COFWE588.6	DO (APC)	9	6	6	-1.54	1.54	1.58
6/5/01 11:45 AM	COFWE588.6	TEMP (APC)	9	6	6	0.23	0.25	0.37

Time	Segment	Constituent	Obs count	Model count	Compared Count	ME	AME	RMS
6/28/01 6:48 AM	RWQMP-WEISS1	DO (WRDB)	12	24	10	-1.72	1.72	2.09
6/28/01 6:48 AM	RWQMP-WEISS1	TEMP (WRDB)	12	24	10	0.99	0.99	1.00
6/28/01 7:42 AM	RWQMP-WEISS2	DO (WRDB)	14	42	11	-1.21	1.84	2.17
6/28/01 7:42 AM	RWQMP-WEISS2	TEMP (WRDB)	14	42	11	0.63	0.63	0.74
7/12/01 9:14 AM	COFWE588.6	DO (APC)	9	6	6	-3.52	3.52	3.94
7/12/01 9:14 AM	COFWE588.6	TEMP (APC)	9	6	6	0.77	0.77	0.90
7/31/01 7:31 AM	RWQMP-WEISS1	DO (WRDB)	14	18	12	0.66	0.66	0.79
7/31/01 7:31 AM	RWQMP-WEISS1	TEMP (WRDB)	14	18	12	-0.25	0.25	0.26
7/31/01 8:51 AM	RWQMP-WEISS2	DO (WRDB)	14	35	12	-1.68	1.83	2.29
7/31/01 8:51 AM	RWQMP-WEISS2	TEMP (WRDB)	14	35	12	1.02	1.02	1.11
8/8/01 3:33 PM	COFWE588.6	DO (APC)	9	6	7	-1.15	1.29	1.45
8/8/01 3:33 PM	COFWE588.6	TEMP (APC)	9	6	7	0.40	0.40	0.44
8/30/01 7:26 AM	RWQMP-WEISS1	DO (WRDB)	13	30	12	1.99	1.99	2.46
8/30/01 7:26 AM	RWQMP-WEISS1	TEMP (WRDB)	13	30	12	-0.79	0.79	0.80
8/30/01 8:23 AM	RWQMP-WEISS2	DO (WRDB)	14	42	13	-0.46	0.63	0.73
8/30/01 8:23 AM	RWQMP-WEISS2	TEMP (WRDB)	14	42	13	-1.16	1.16	1.17
9/10/01 9:42 AM	COFWE588.6	DO (APC)	9	6	6	-3.36	3.36	3.59
9/10/01 9:42 AM	COFWE588.6	TEMP (APC)	9	6	6	-0.99	0.99	1.11
9/25/01 7:09 AM	RWQMP-WEISS1	DO (WRDB)	13	24	12	-0.93	0.93	0.93
9/25/01 7:09 AM	RWQMP-WEISS1	TEMP (WRDB)	13	24	12	-0.57	0.60	0.66
9/25/01 8:10 AM	RWQMP-WEISS2	DO (WRDB)	13	35	12	0.30	0.30	0.34
9/25/01 8:10 AM	RWQMP-WEISS2	TEMP (WRDB)	13	35	12	-0.69	0.69	0.70

9. Figures

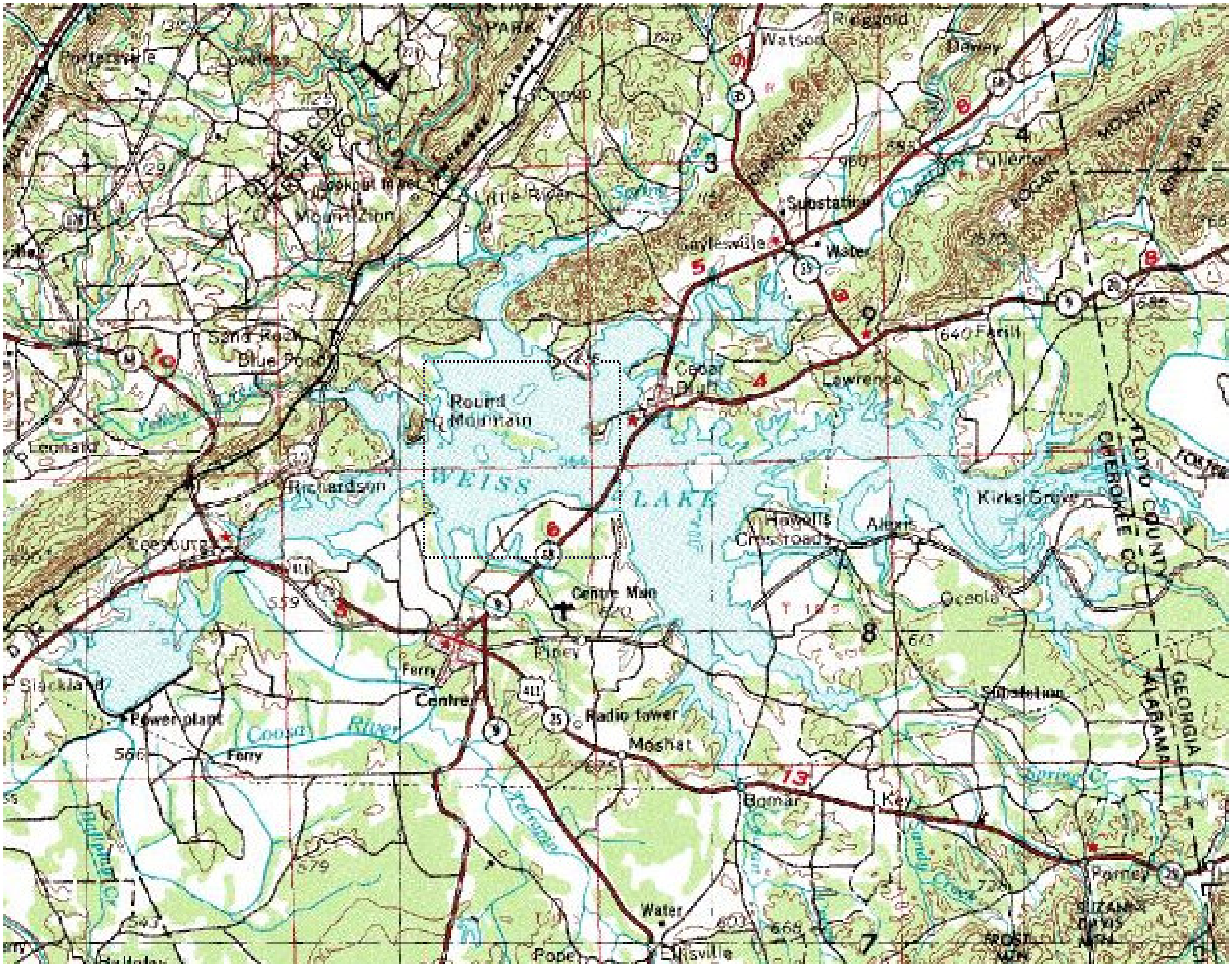


Figure 1 Topographical map of Weiss Lake and surrounding areas

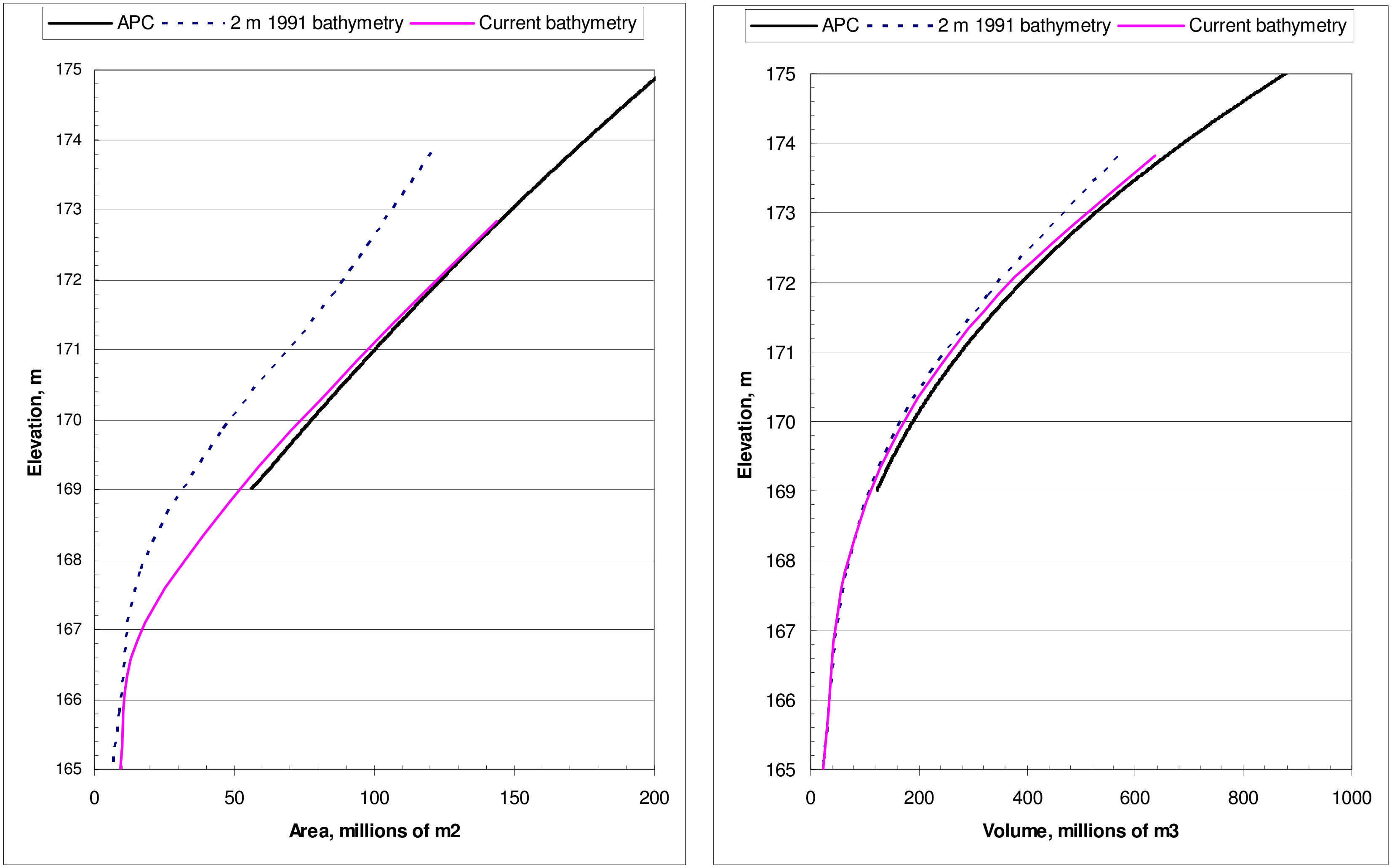


Figure 2 Volume-area-elevation comparisons of current and original grid

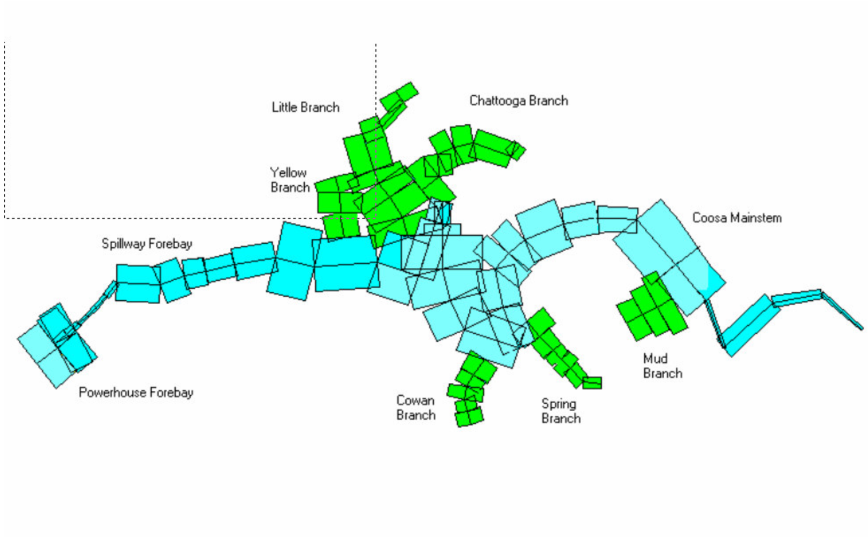


Figure 3 Grid used in the original TMDL calibration report

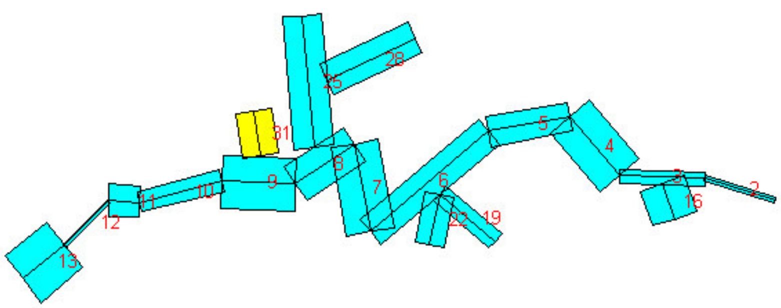


Figure 4 Model grid with branches merged into one segment each

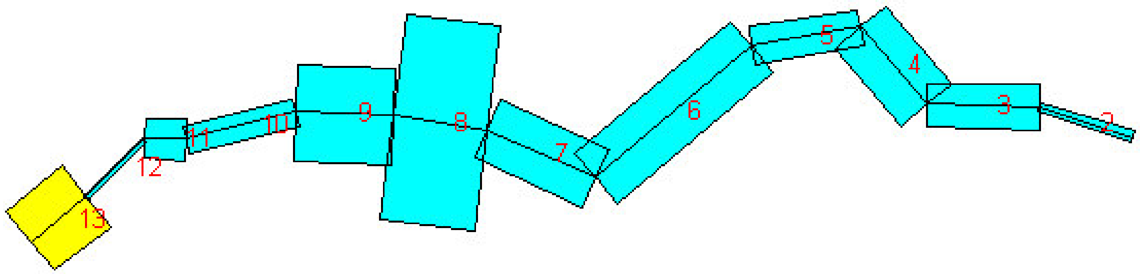


Figure 5 Final model grid
The two compliance points are located in Segment 7 and Segment 13. The corresponding sampling stations are referred to as Weiss2 and Weiss1 respectively.

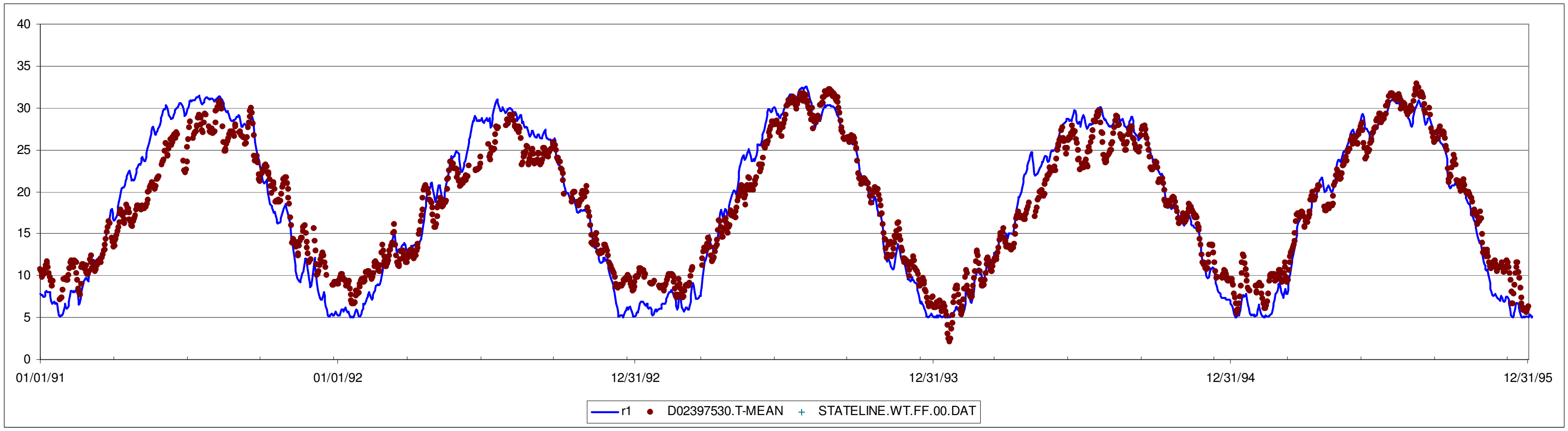


Figure 6 1991 to 1995 mainstem temperature observations and computed response temperature

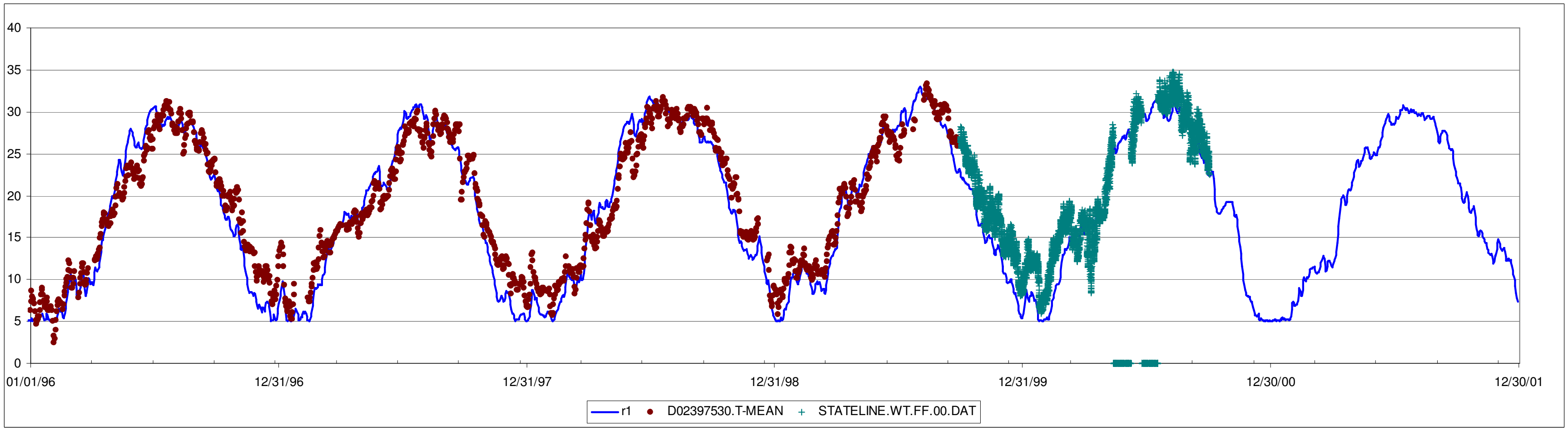


Figure 7 1996 to 2001 tributary temperature observations and computed response temperature

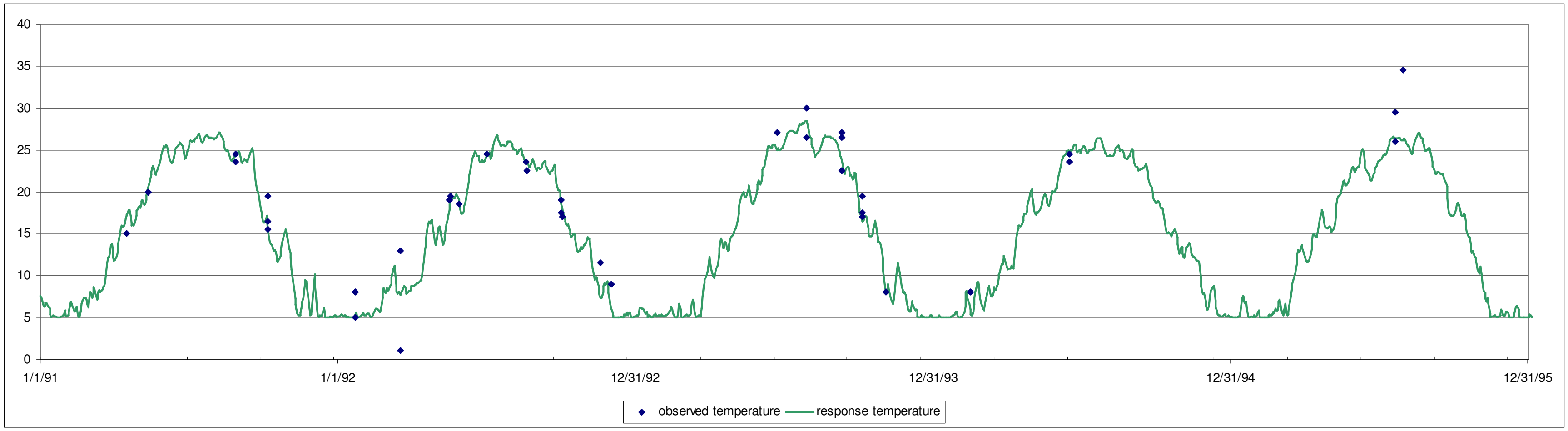


Figure 8 1991 to 1995 tributary temperature observations and computed response temperature

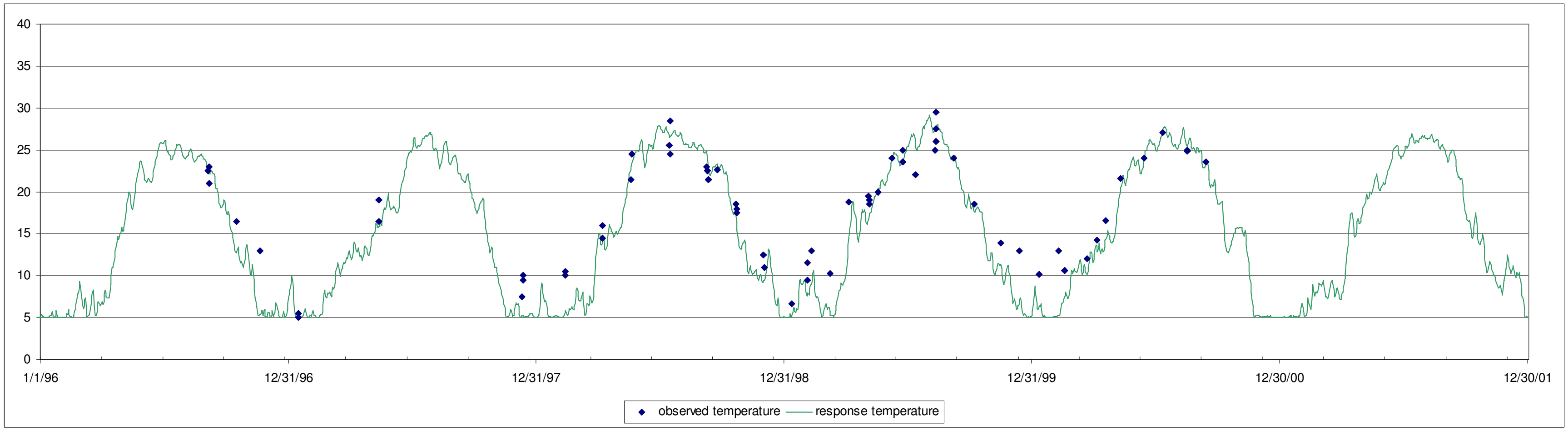


Figure 9 1996 to 2001 tributary temperature observations and computed response temperature.

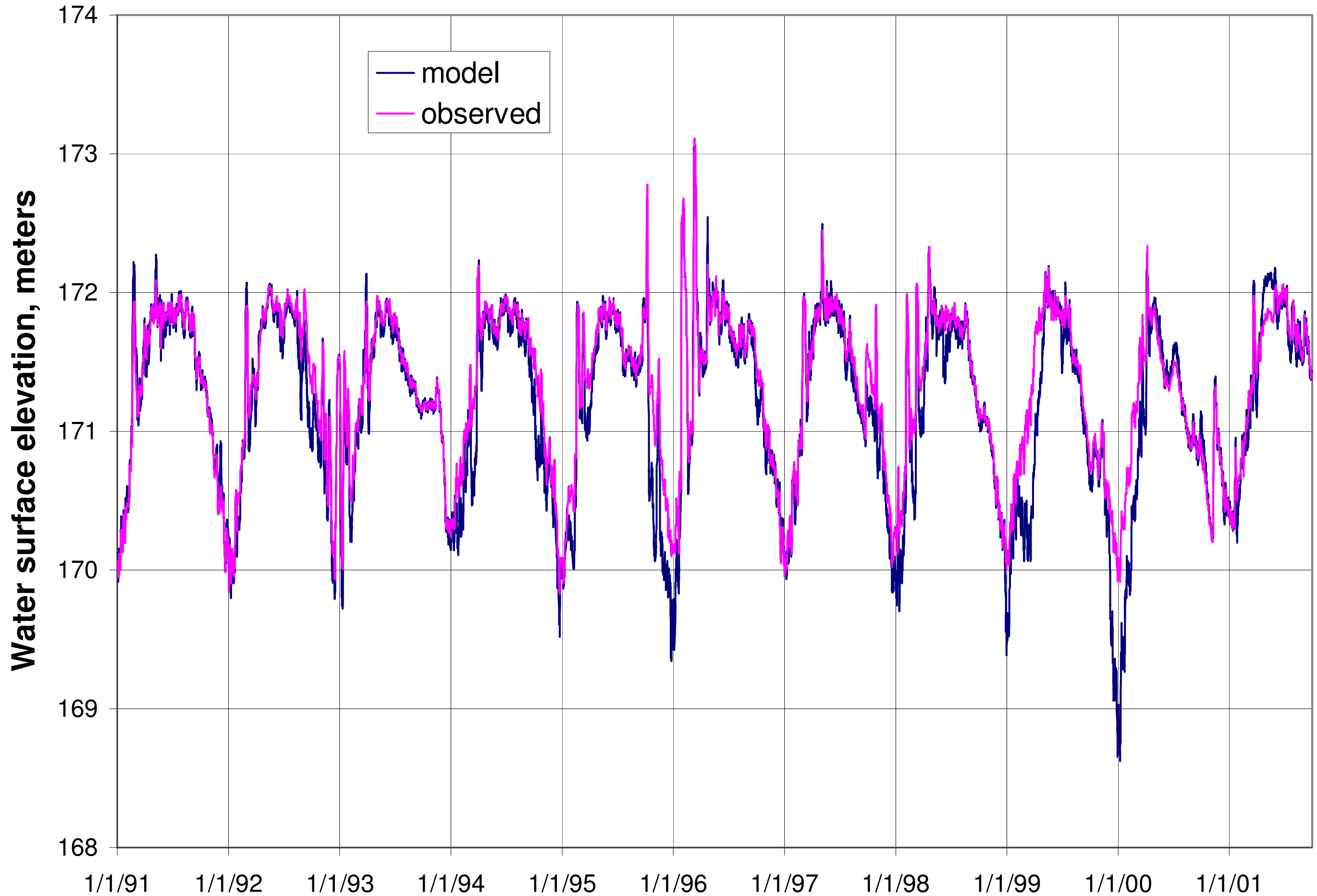


Figure 10 Comparison of modeled and observed water surface elevation

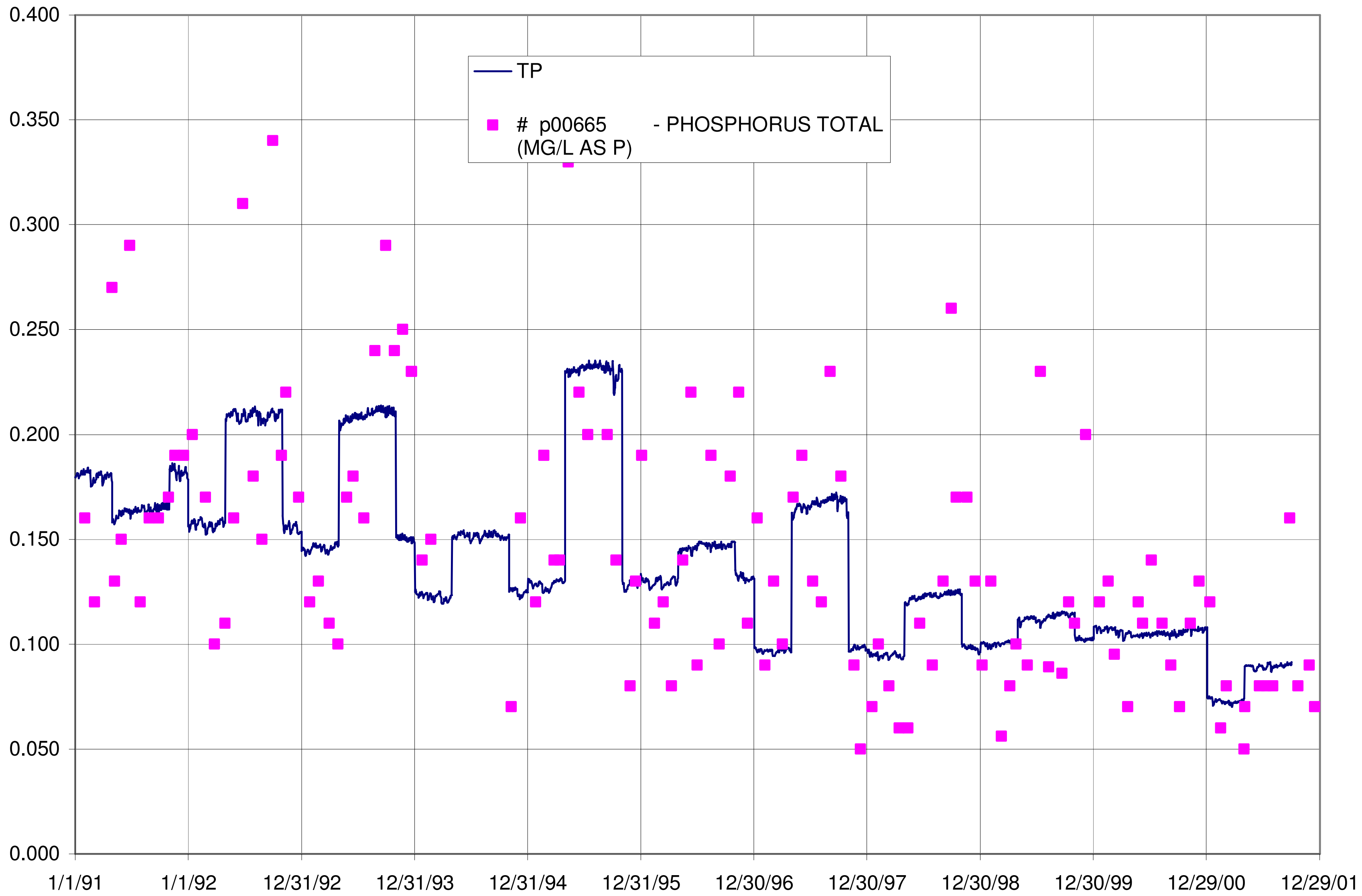


Figure 11 Coosa River inflow Total Phosphorus estimated and observed concentration time series

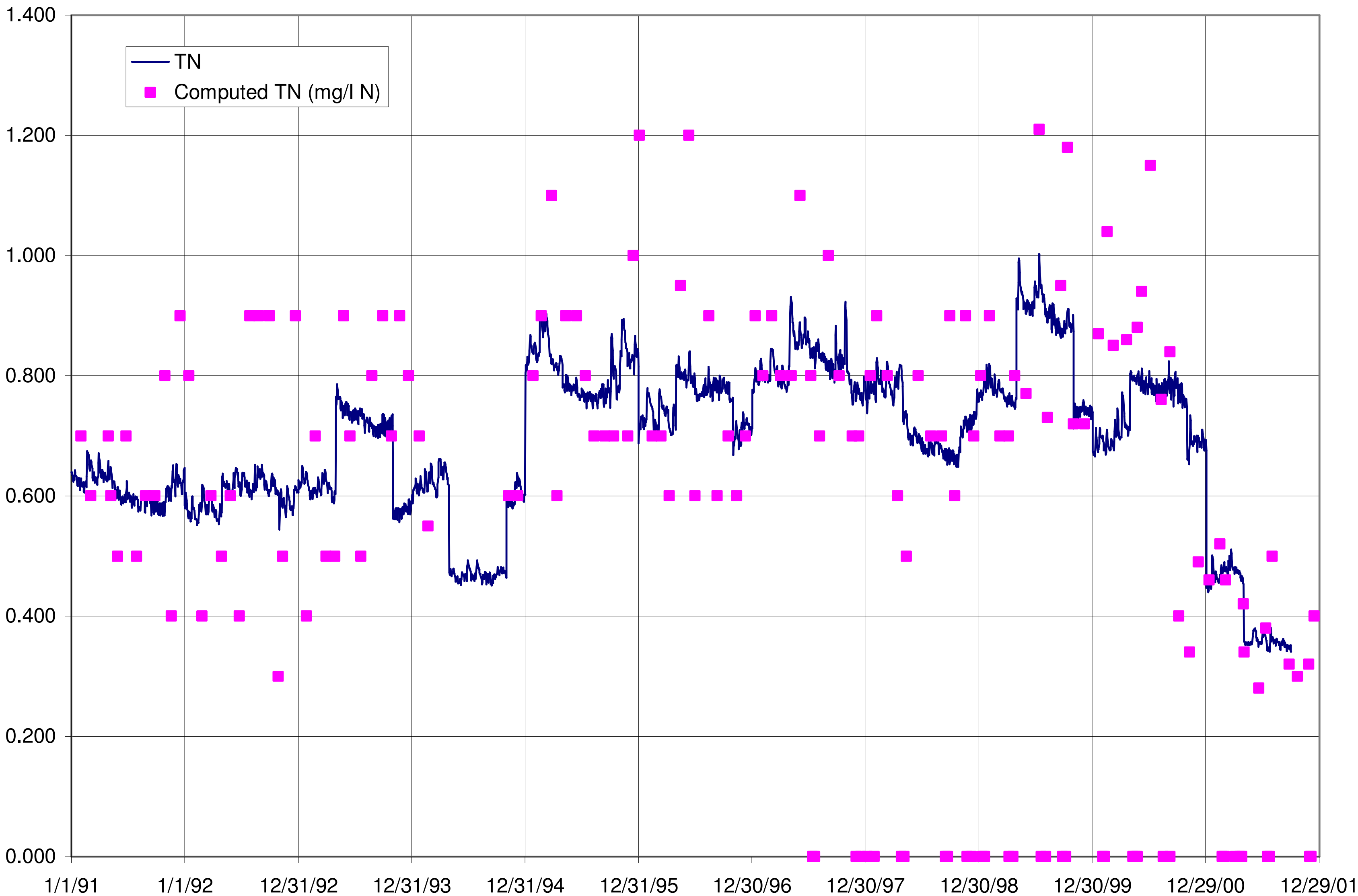


Figure 12 Coosa River inflow Total Nitrogen estimated and observed concentration time series

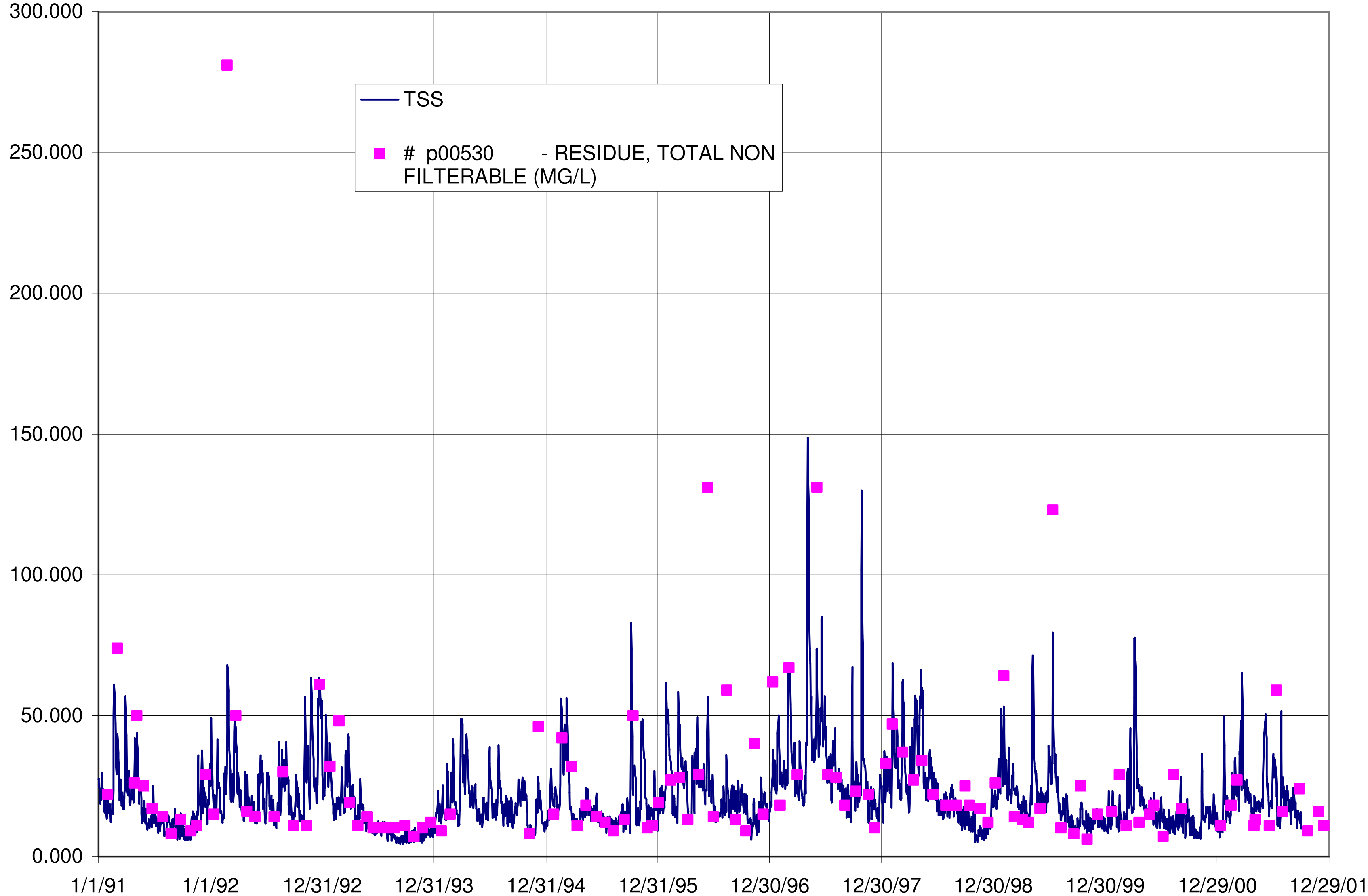


Figure 13 Coosa River inflow Total Suspended Solids estimated and observed concentration time series

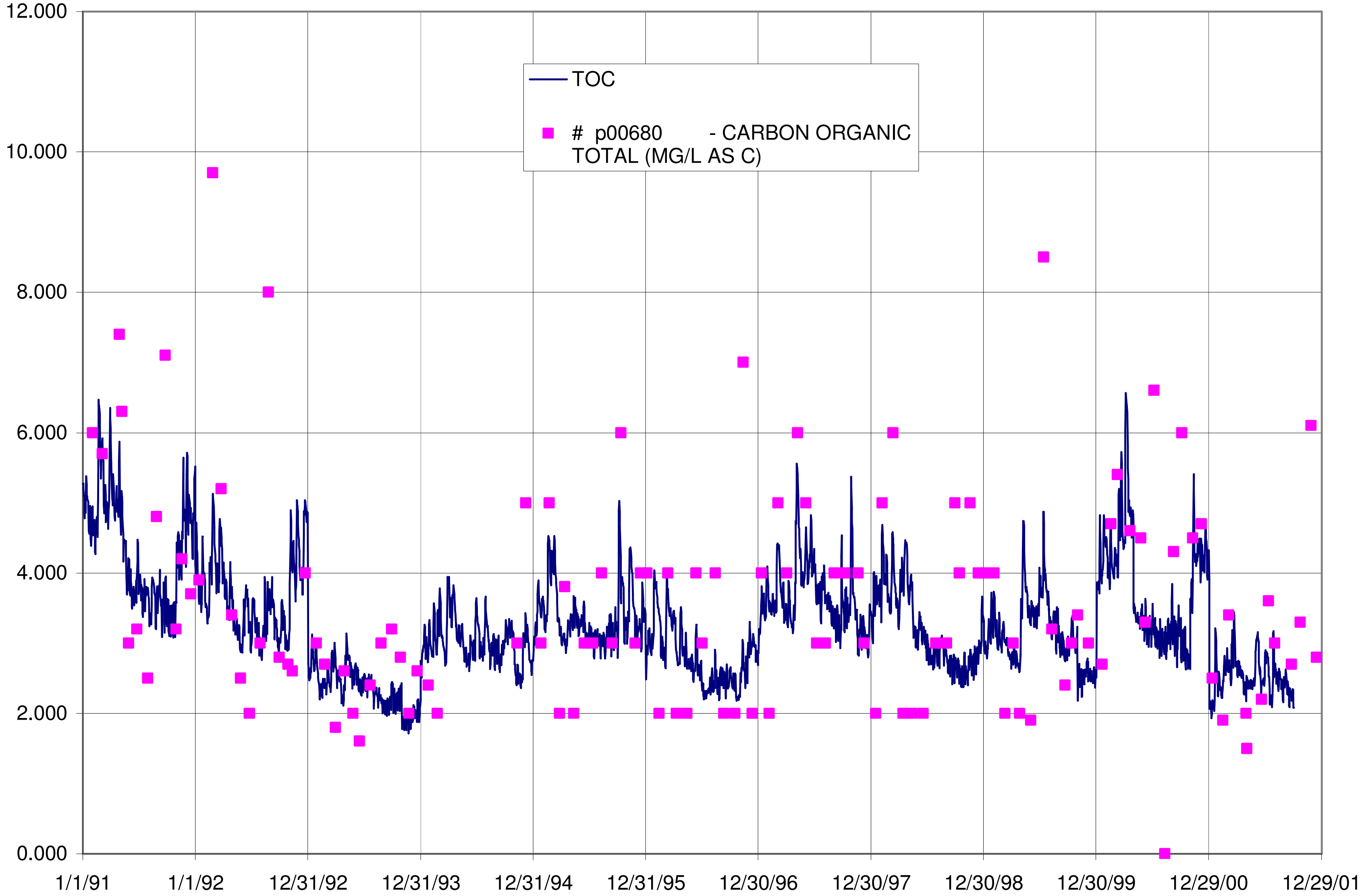


Figure 14 Coosa River inflow Total Organic Carbon estimated and observed concentration time series

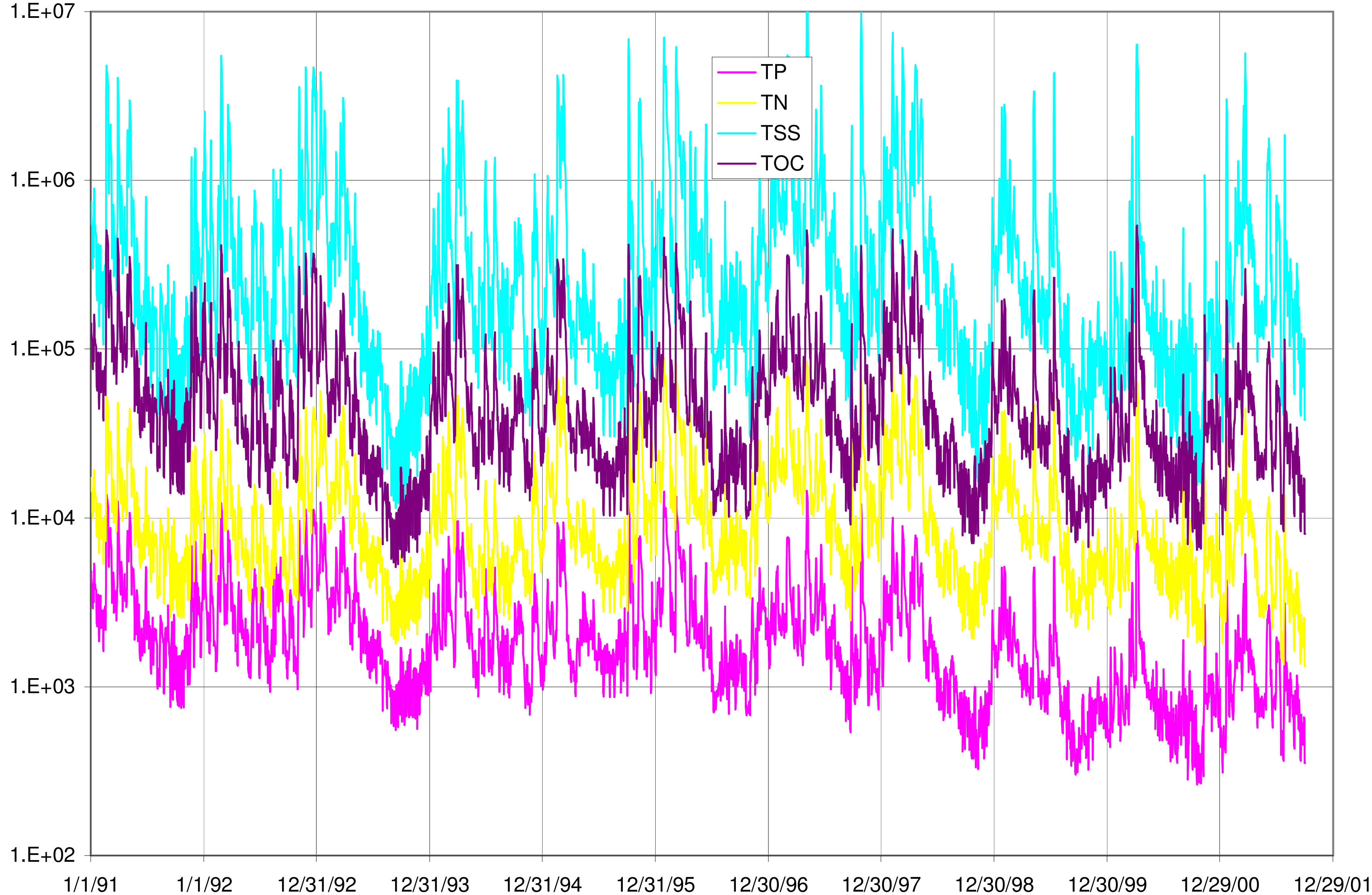


Figure 15 Daily average estimated Coosa River inflow load in kg/day for various constituents

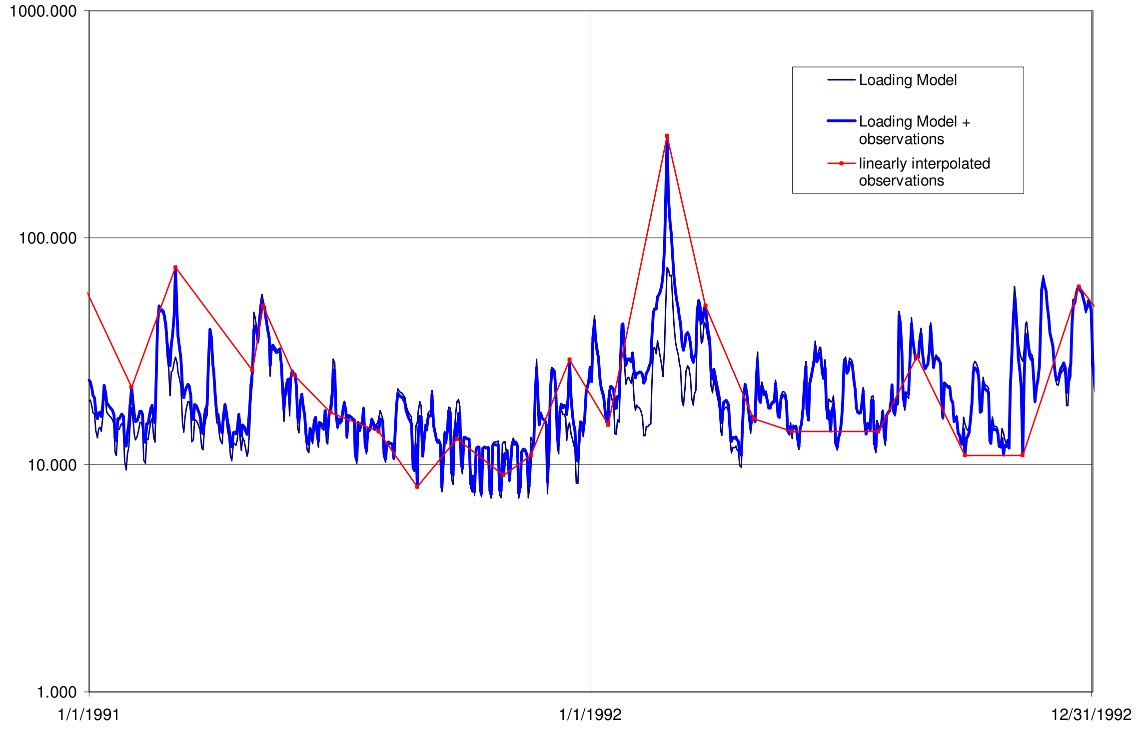


Figure 16 Short time series section illustrating the smoothing procedure
This figure illustrates how the smoothing procedure honors the data and the model, and provides a result that is likely more appropriate than either the observation record or the model estimates

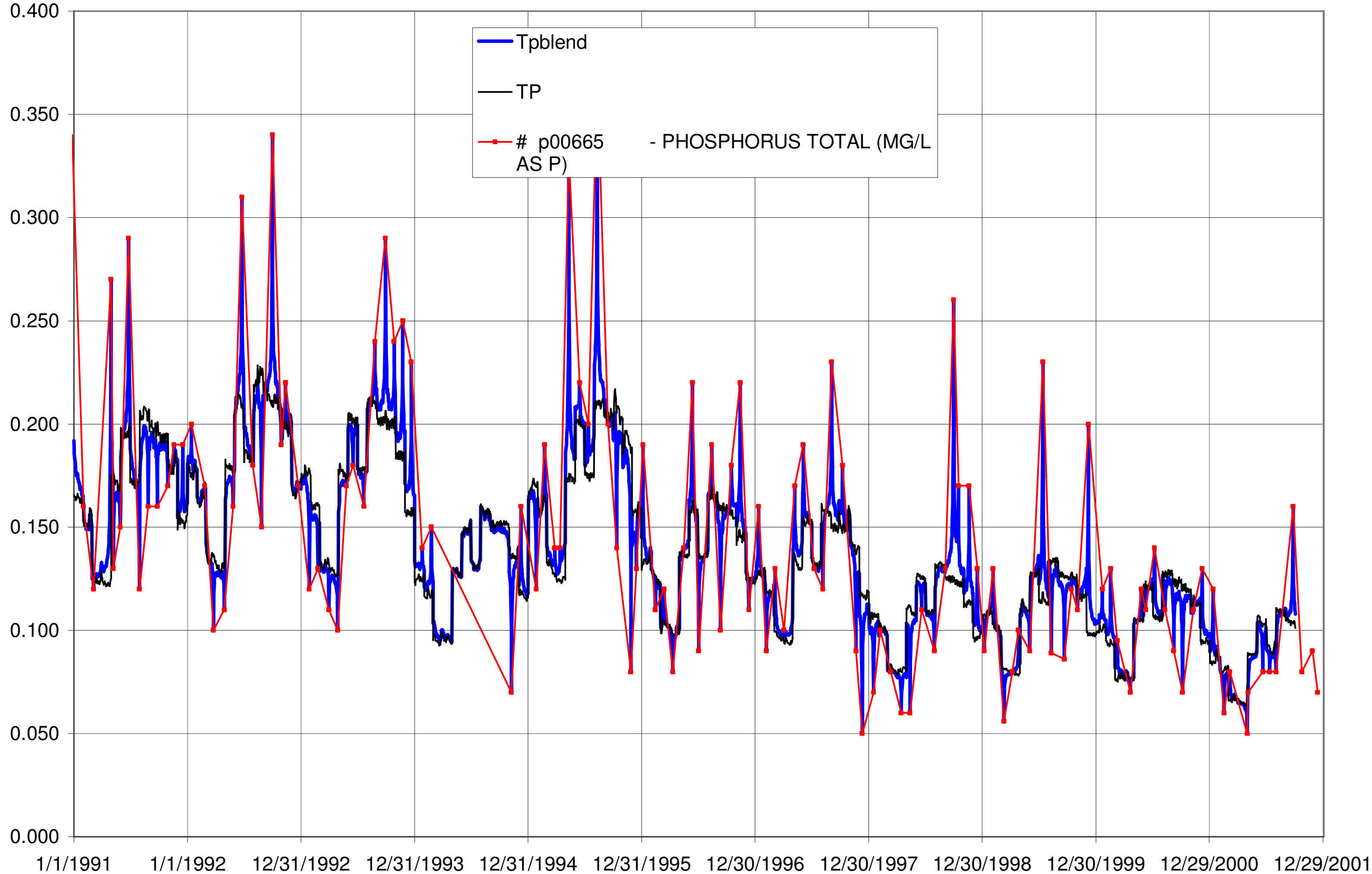


Figure 17 Coosa River inflow Total Phosphorus estimated and observed concentration time series (revised and final)

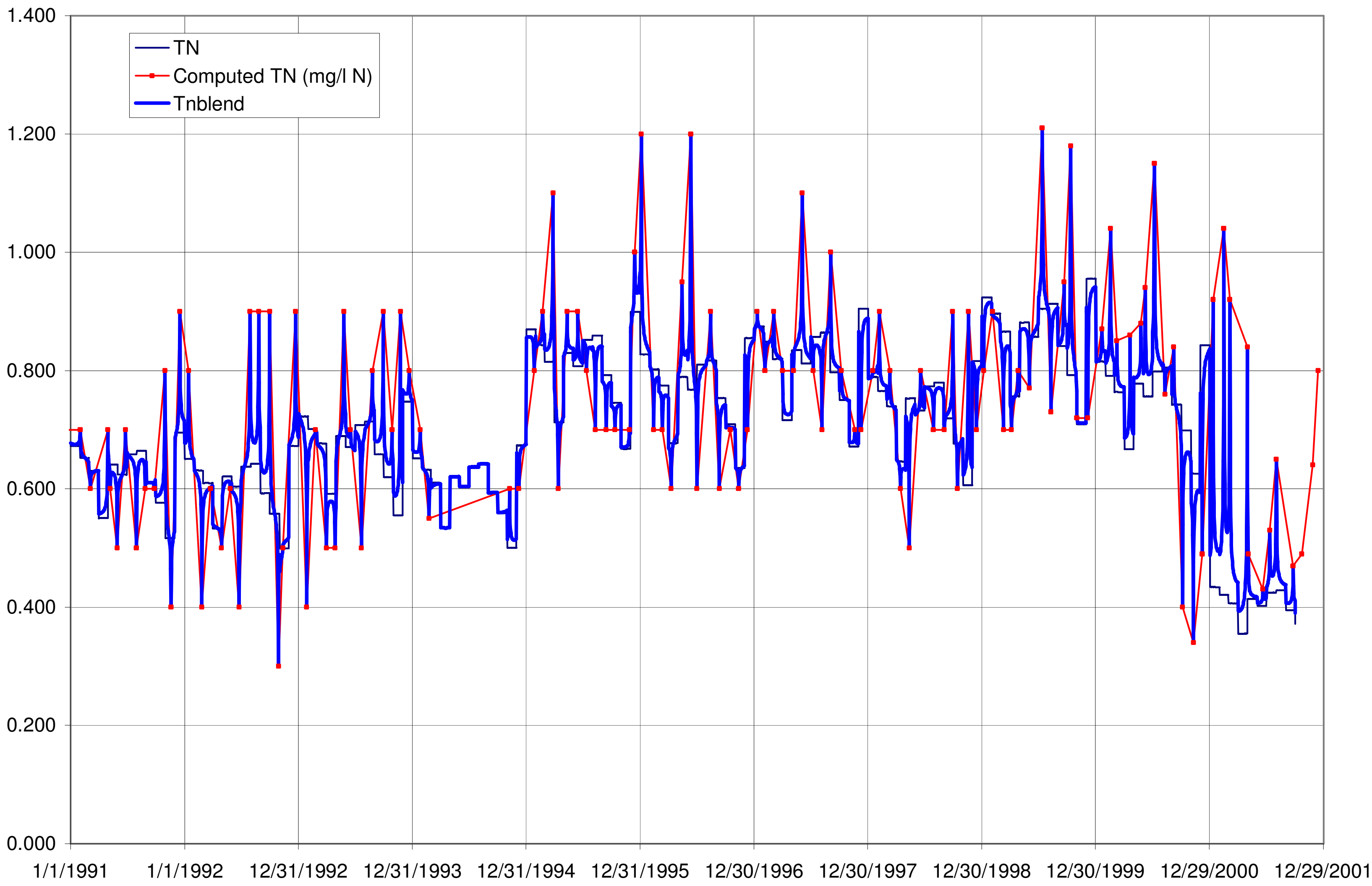


Figure 18 Coosa River inflow Total Nitrogen estimated and observed concentration time series (revised and final)

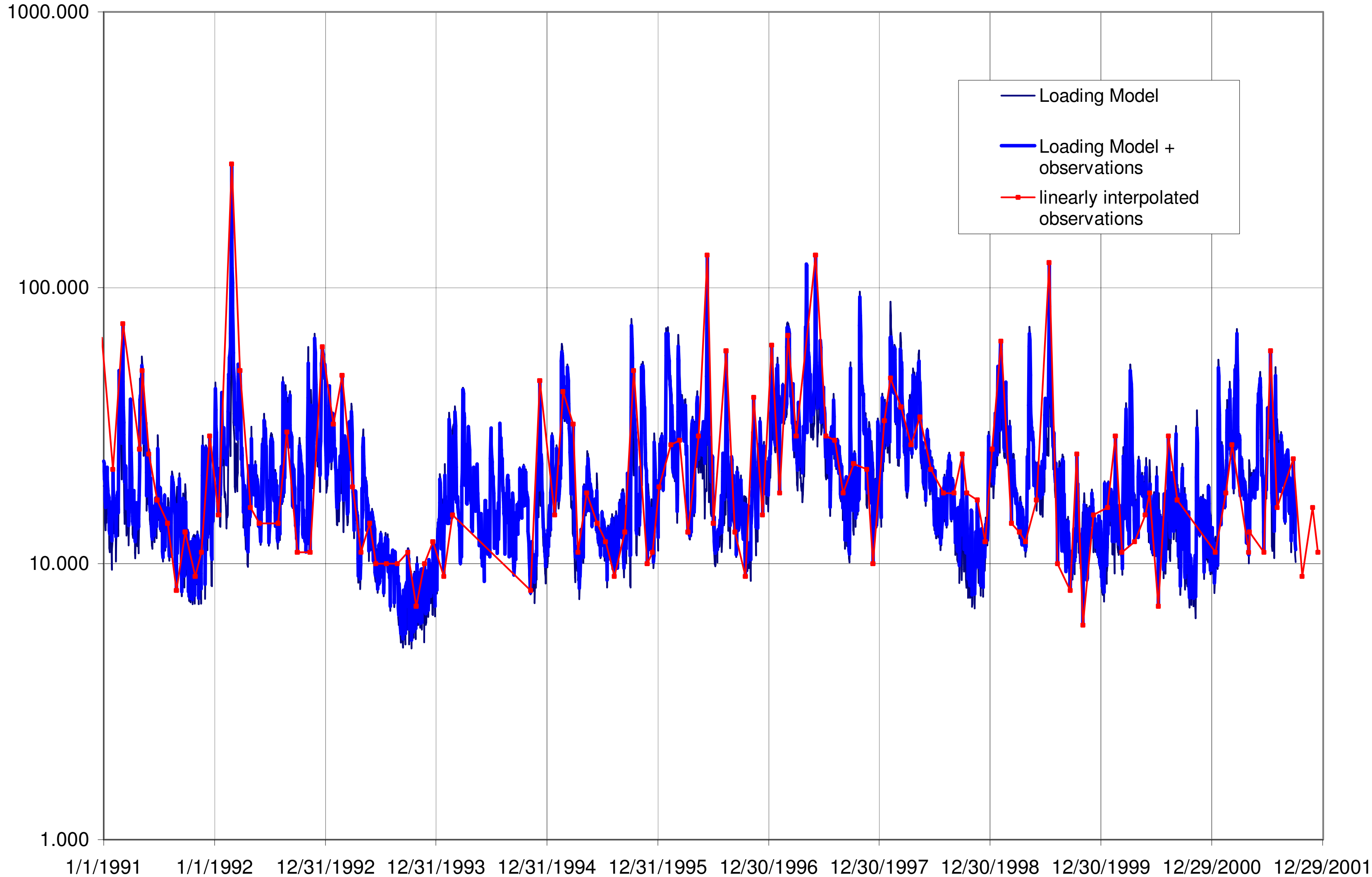


Figure 19 Coosa River inflow Total Suspended Solids estimated and observed concentration time series (revised and final)

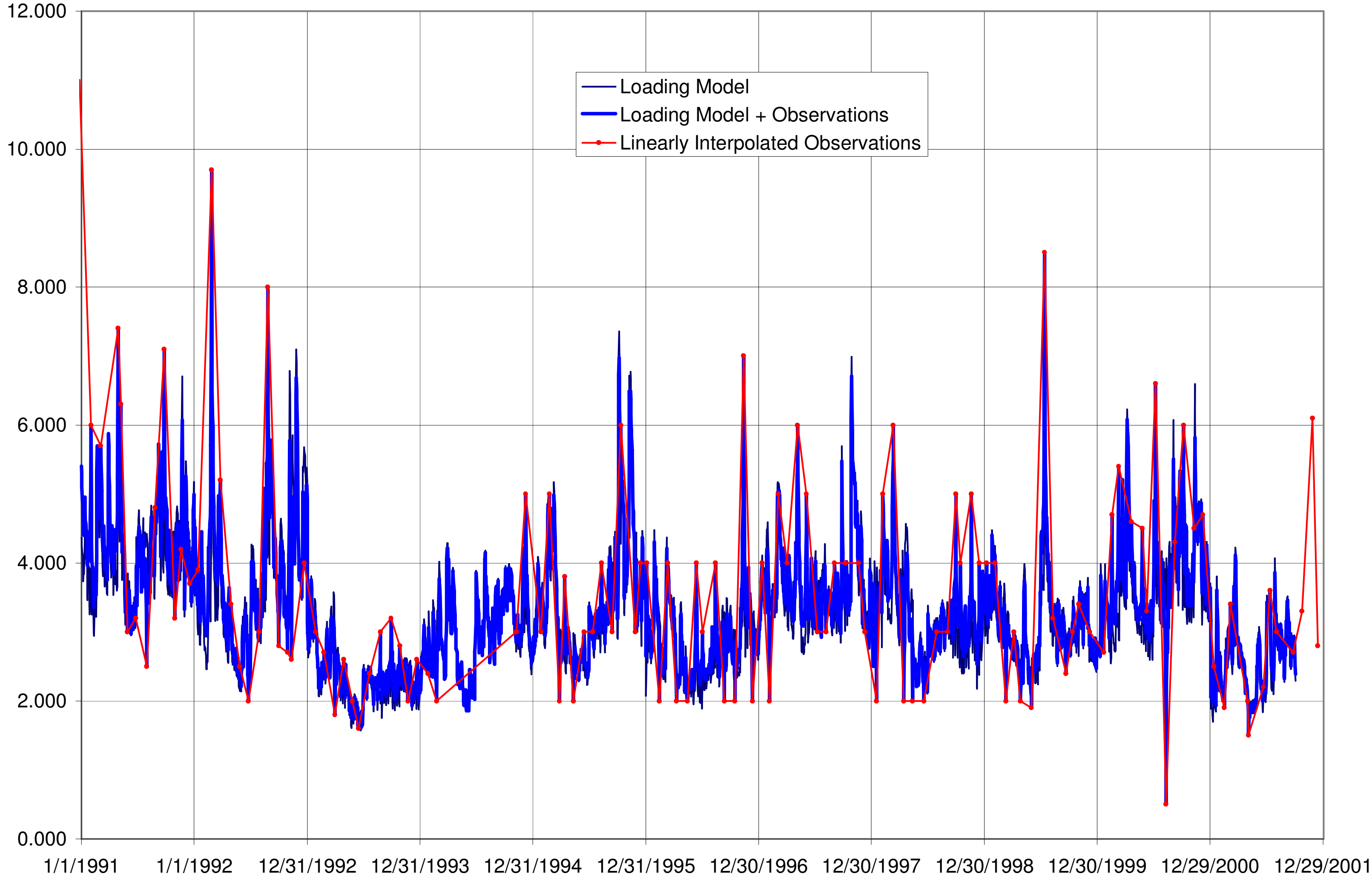


Figure 20 Coosa River inflow Total Organic Carbon estimated and observed concentration time series (revised and final)

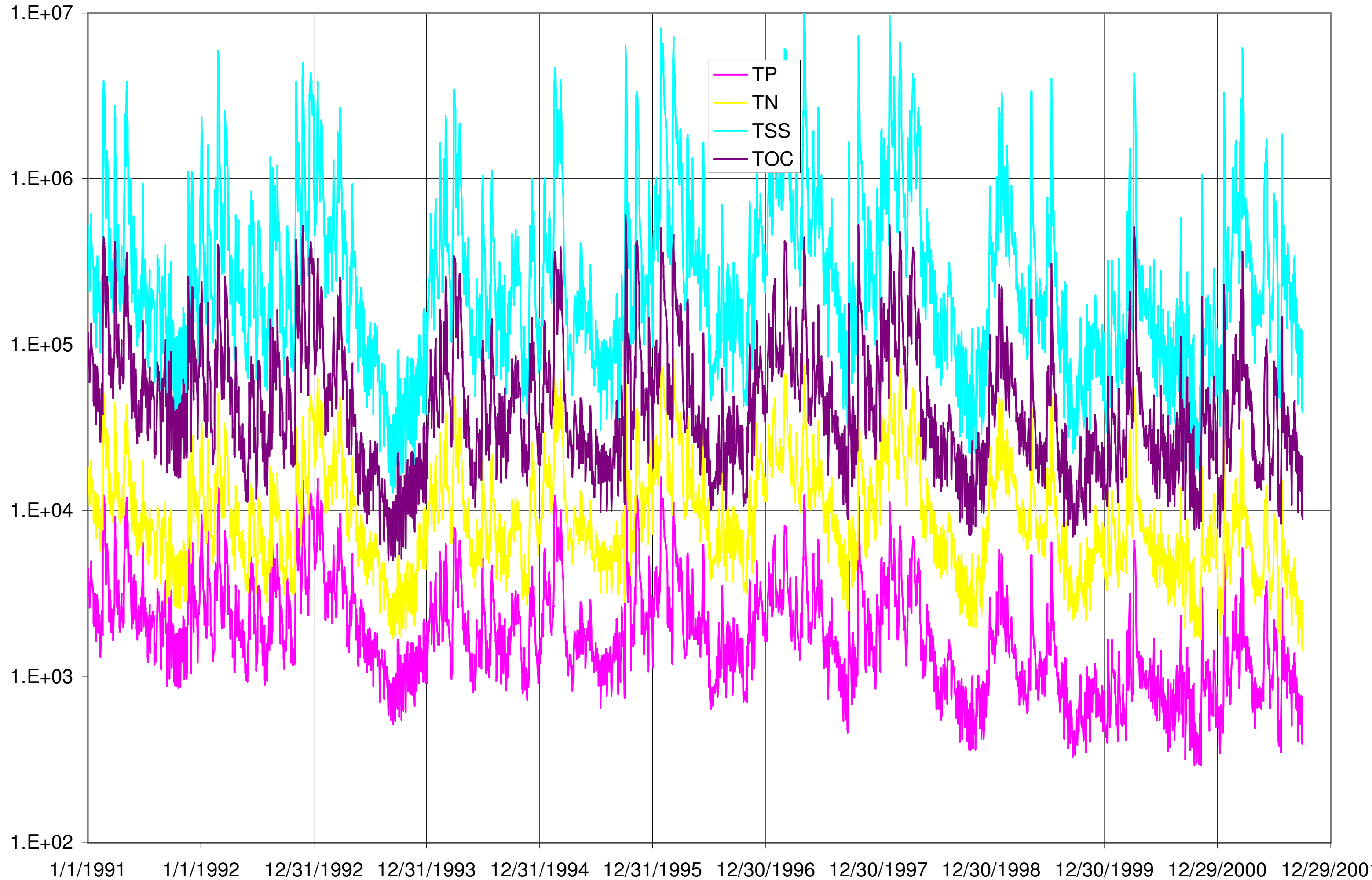


Figure 21 Daily average estimated Coosa River inflow load in kg/day for various constituents (revised and final)

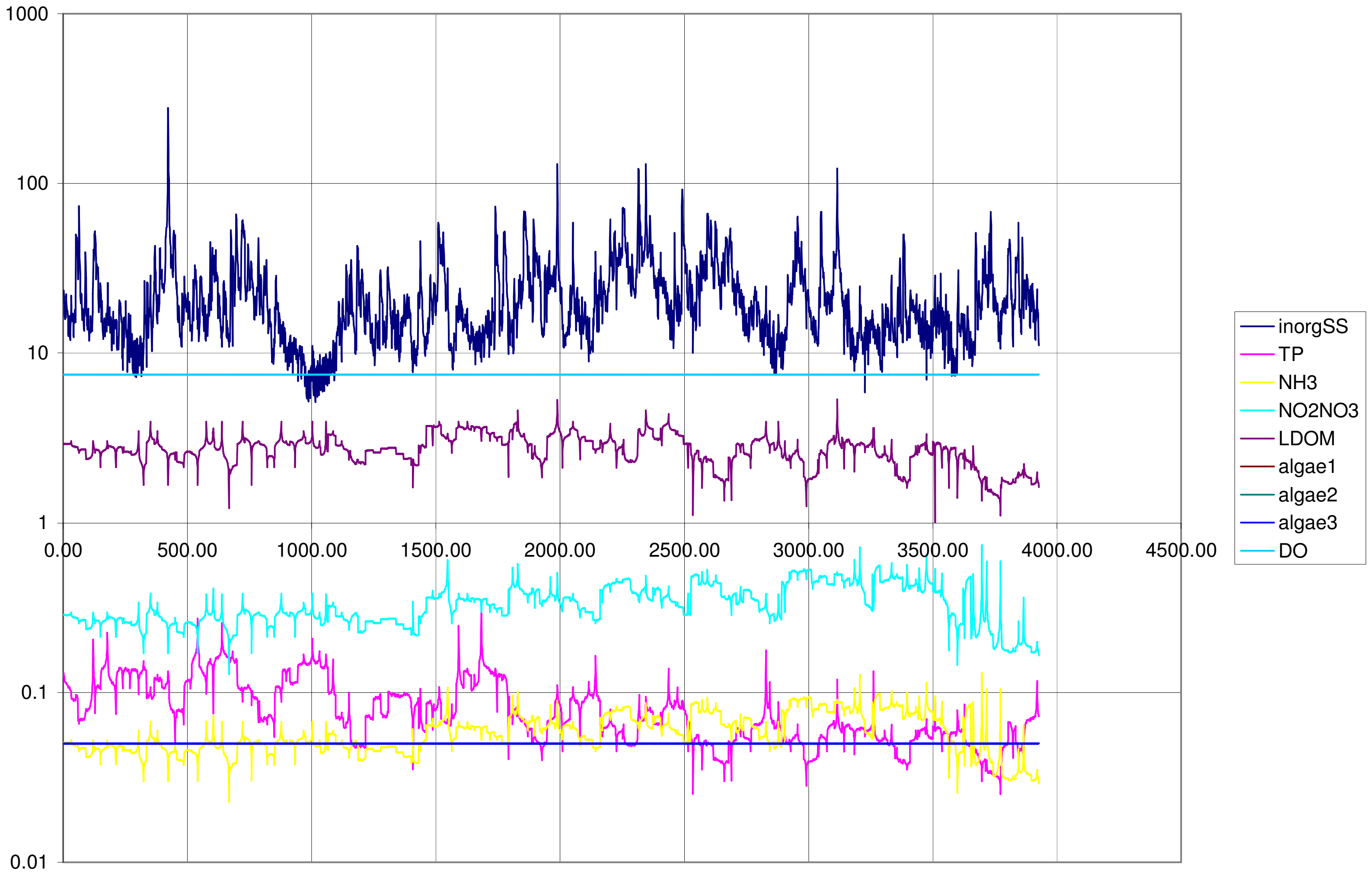


Figure 22 Time series of CE-QUAL-W2 constituent input for Coosa River inflow (revised and final)

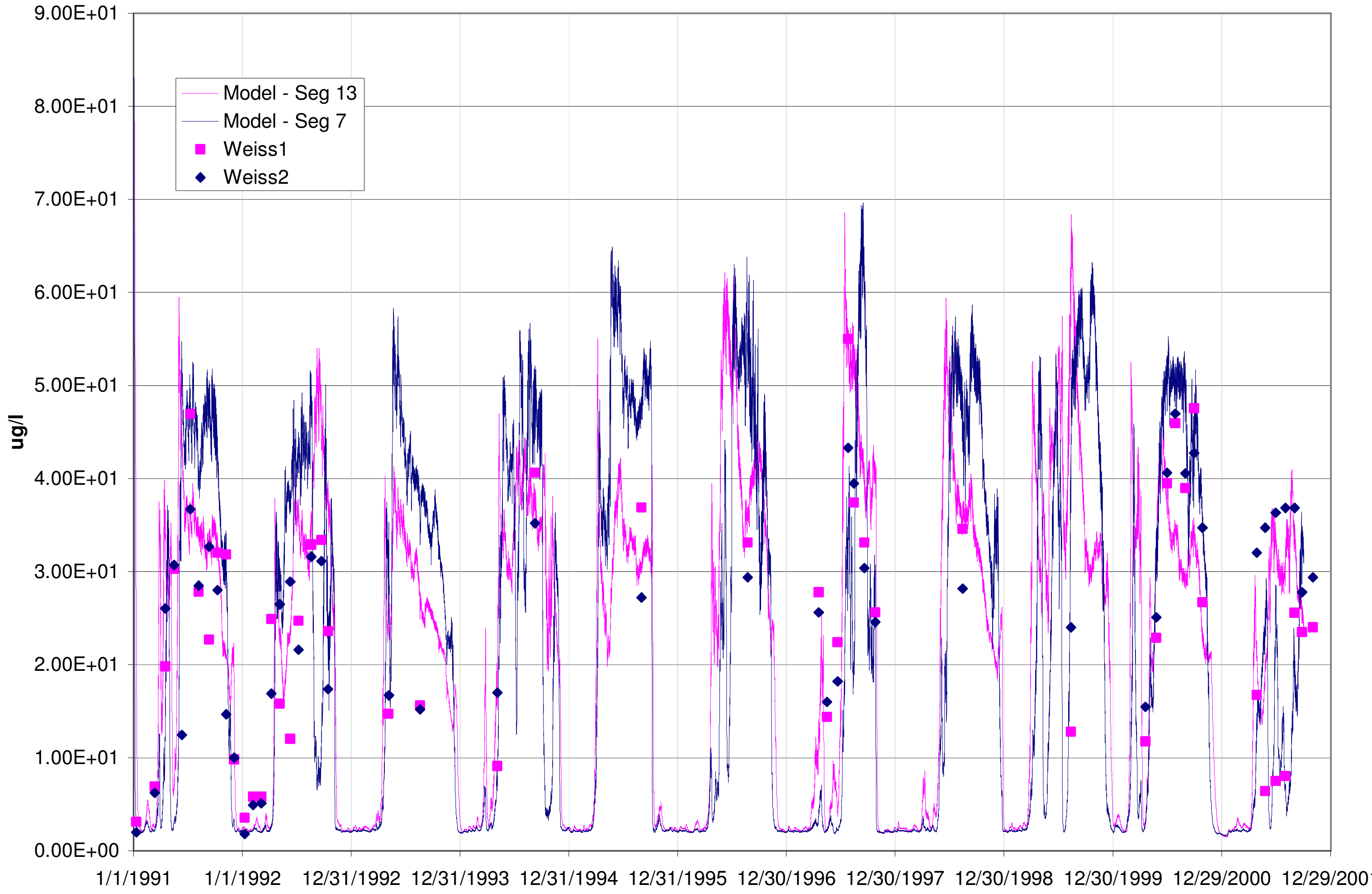


Figure 23 Time series of predicted and observed Chlorophyll a (Chla)

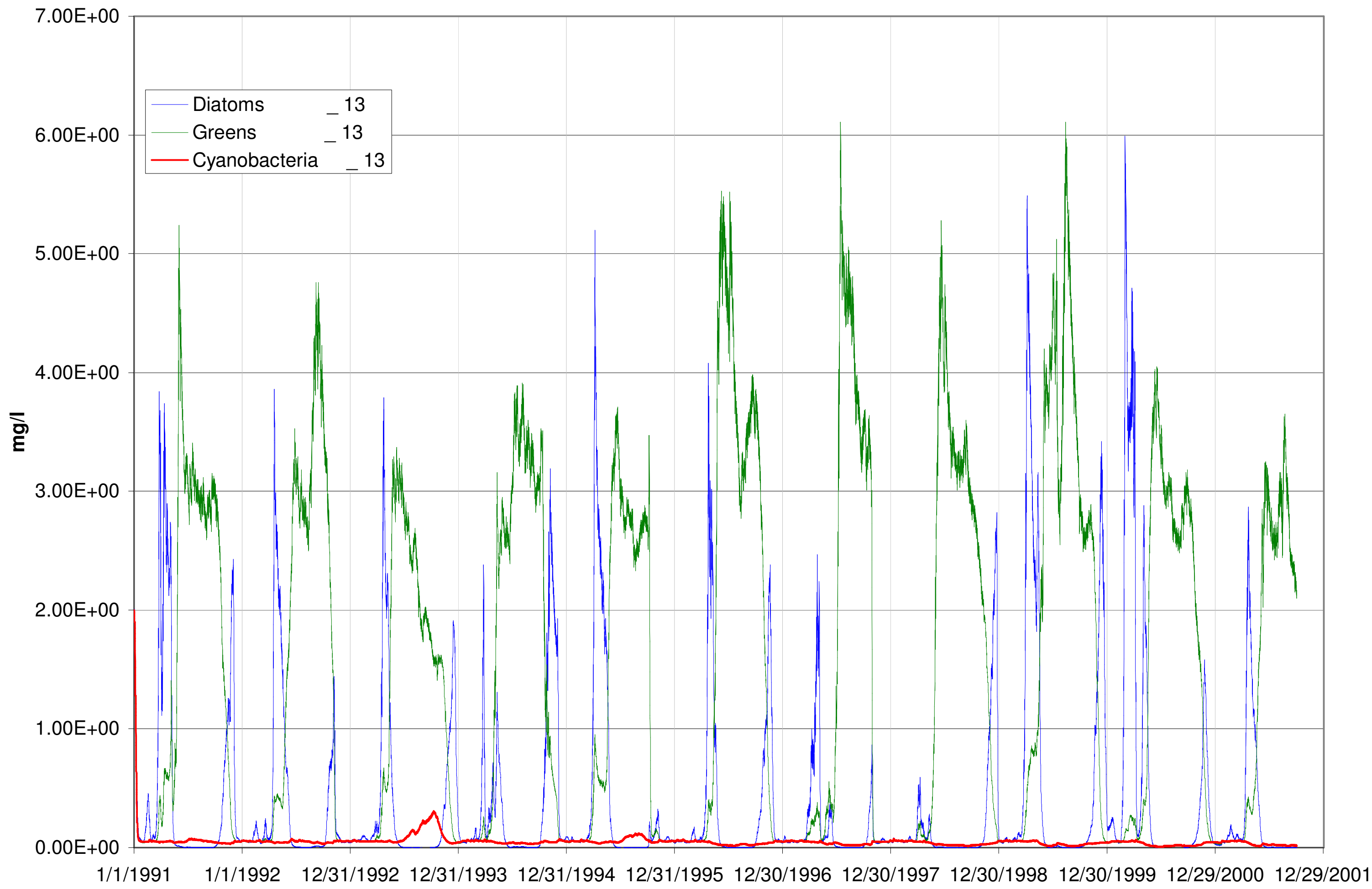


Figure 24 Time series of the three algal components included in the model, in units of mg/l algal organic matter, at Weiss1

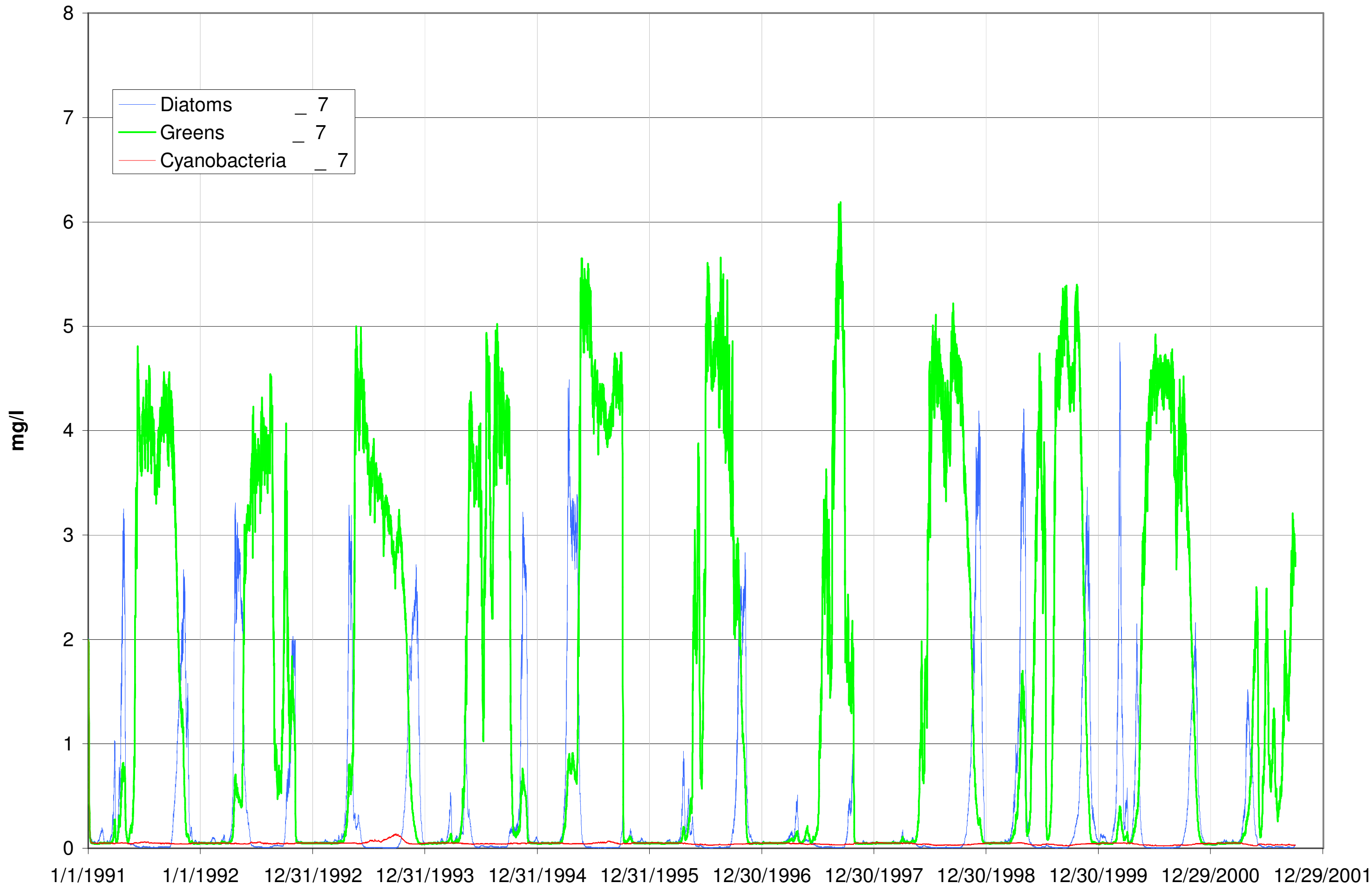


Figure 25 Time series of the three algal components included in the model, in units of mg/l algal organic matter, at Weiss2

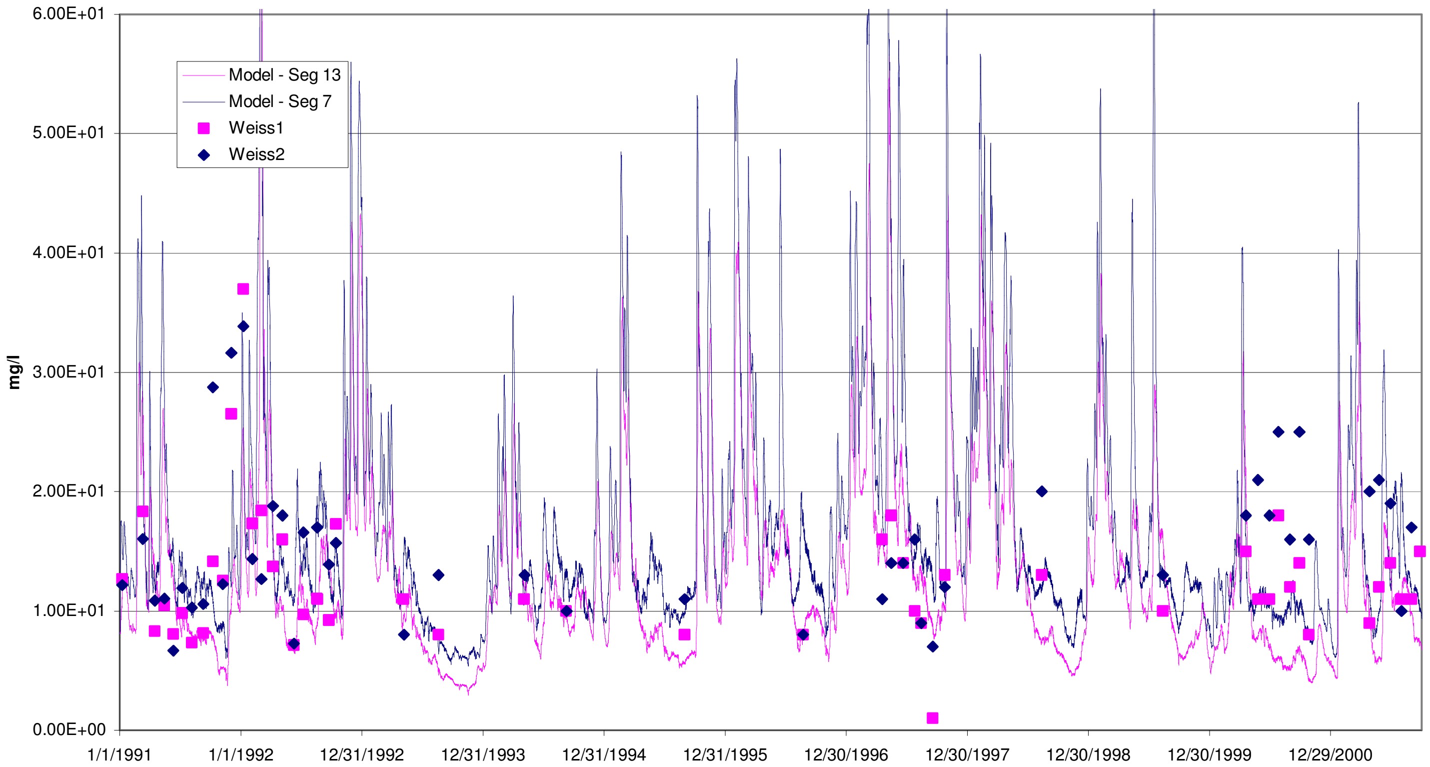


Figure 26 Time series of predicted and observed Total Suspended Solids (TSS)

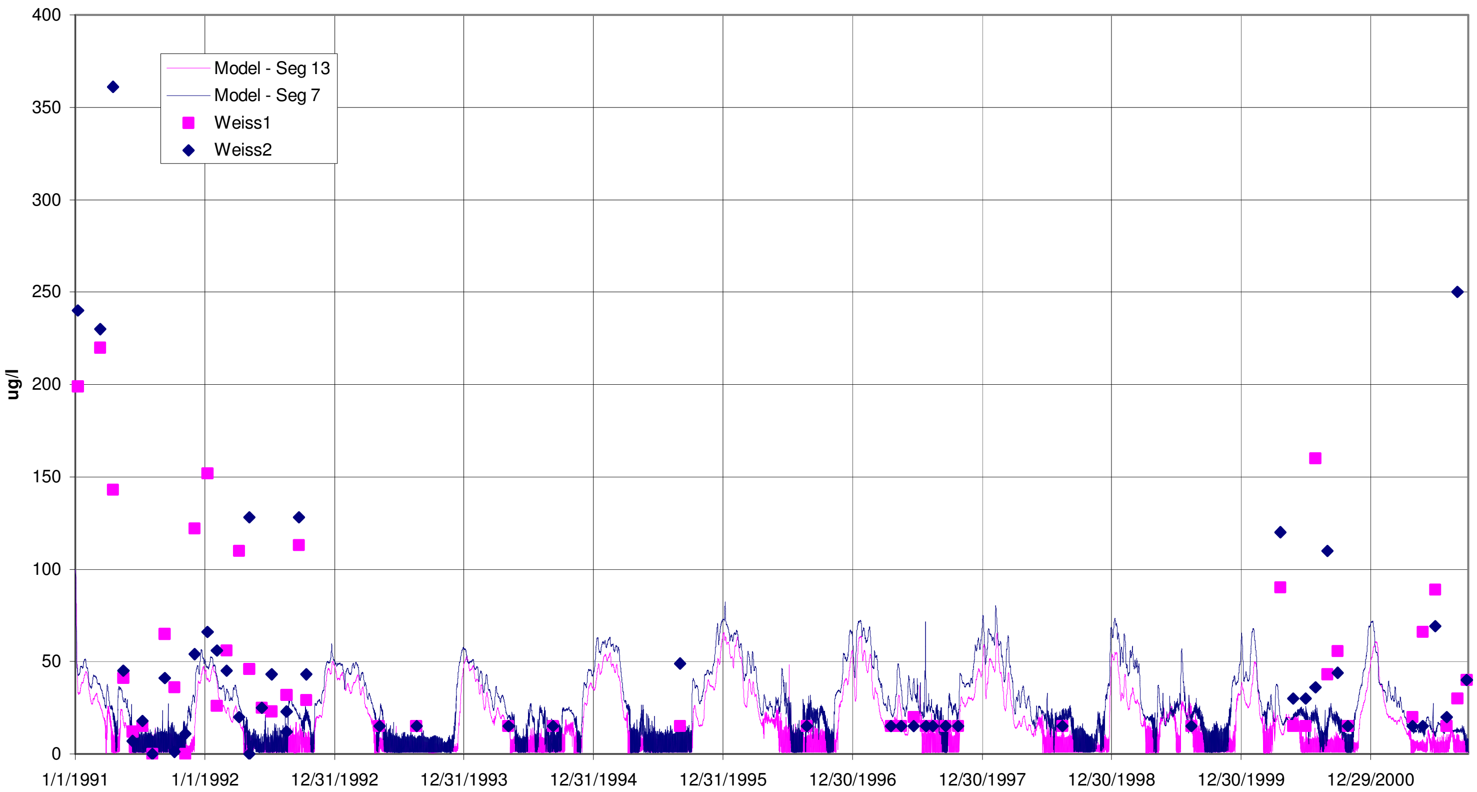


Figure 27 Time series of predicted and observed Ammonia

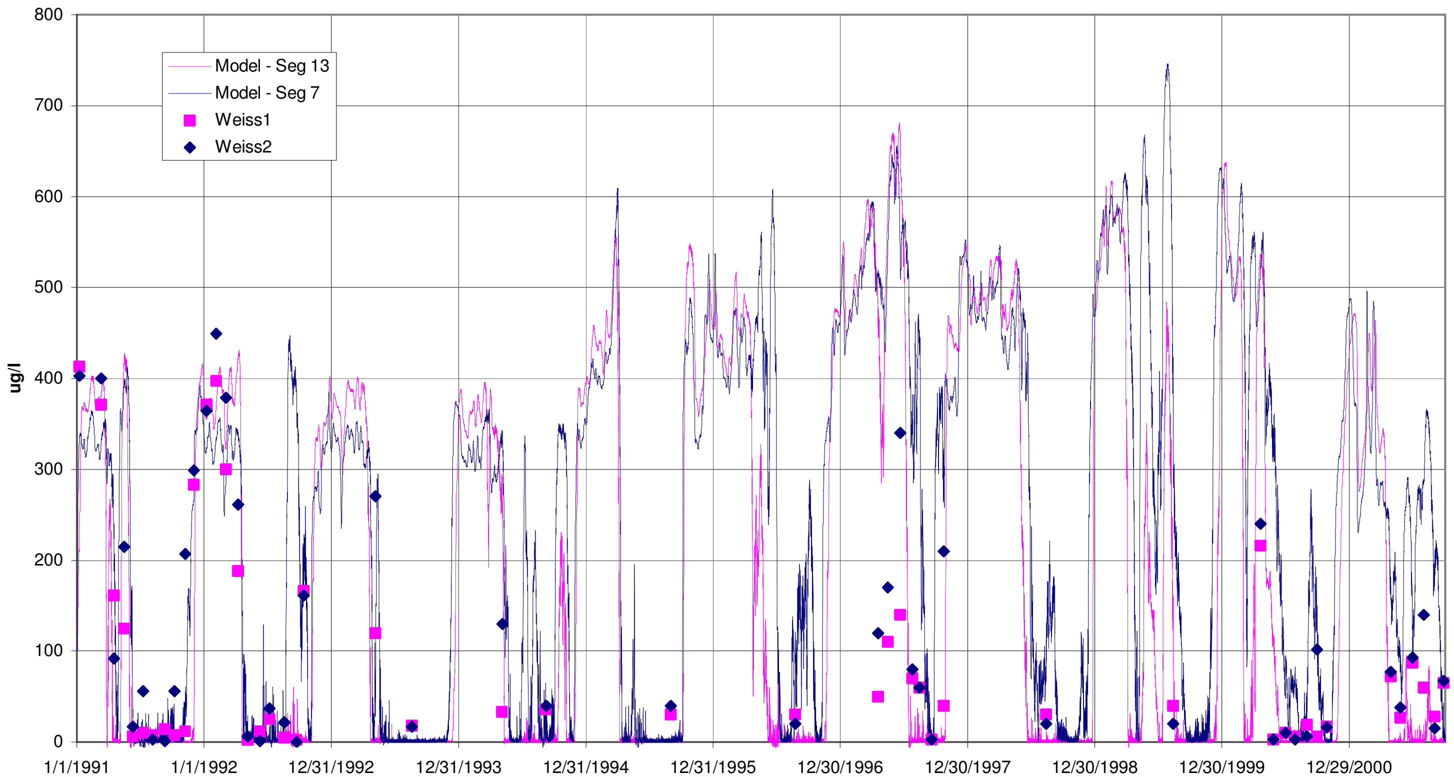


Figure 28 Time series of predicted and observed Nitrate

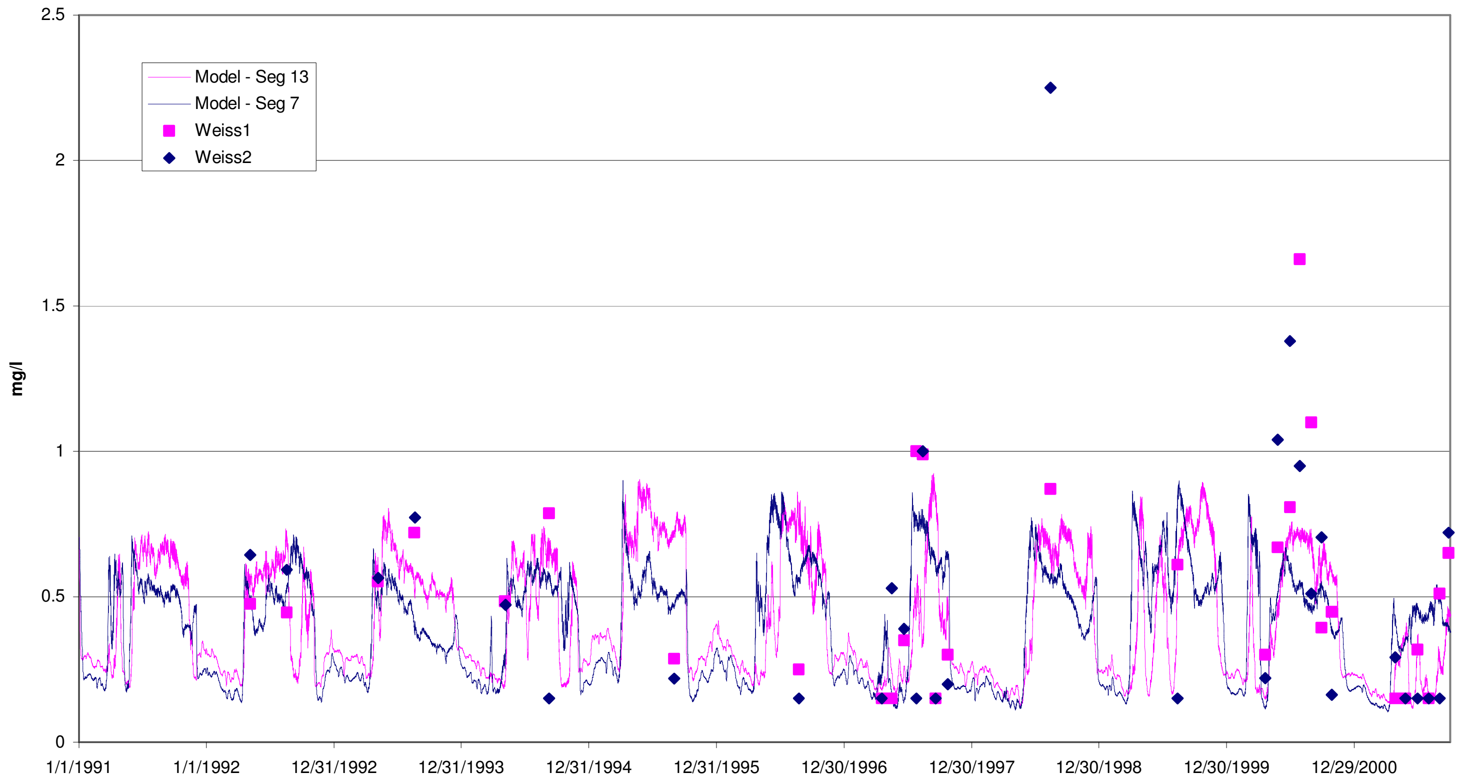


Figure 29 Time series of predicted and observed Total Kjeldahl Nitrogen (TKN)

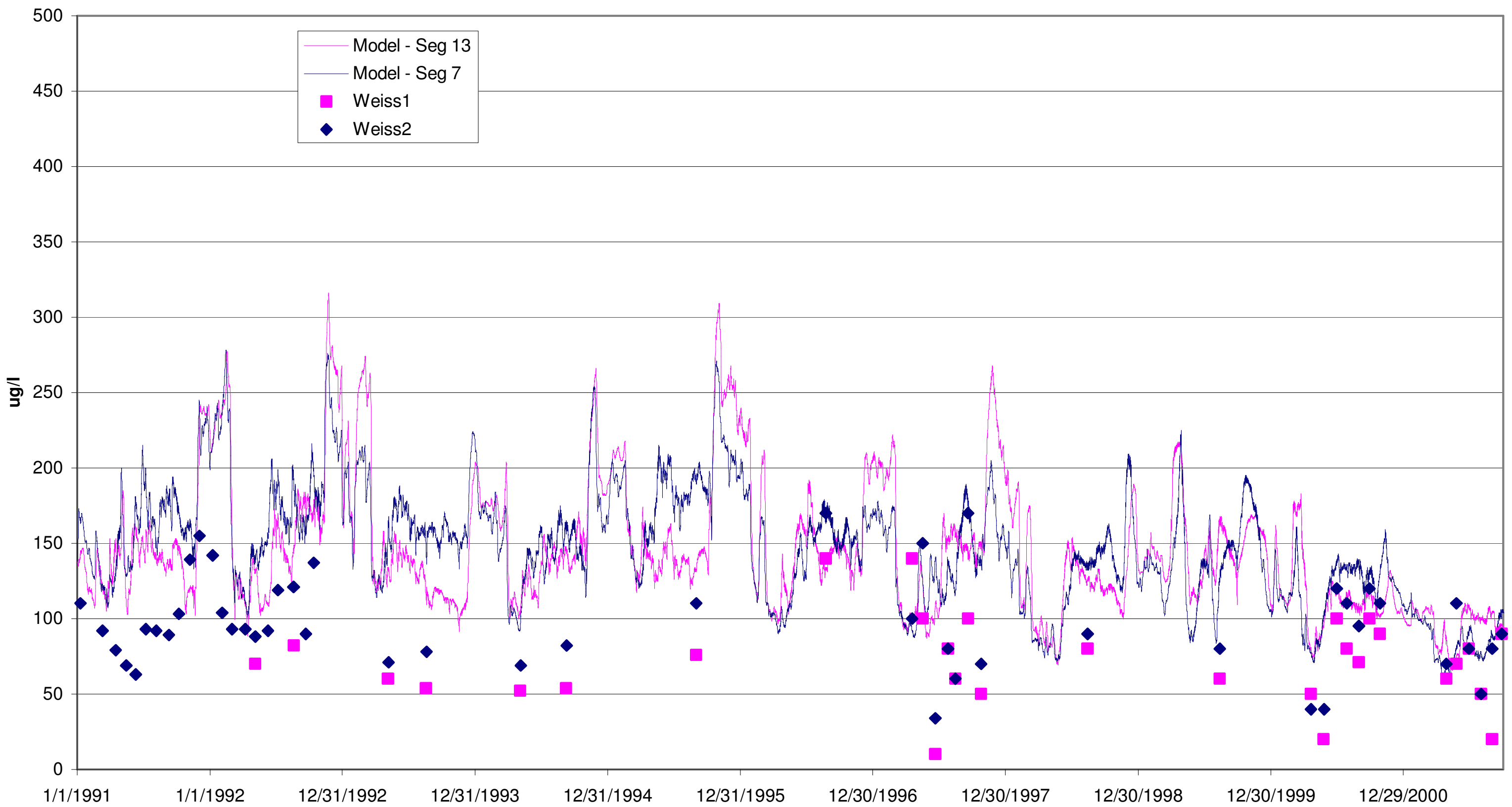


Figure 30 Time series of predicted and observed Total Phosphorus (TP)

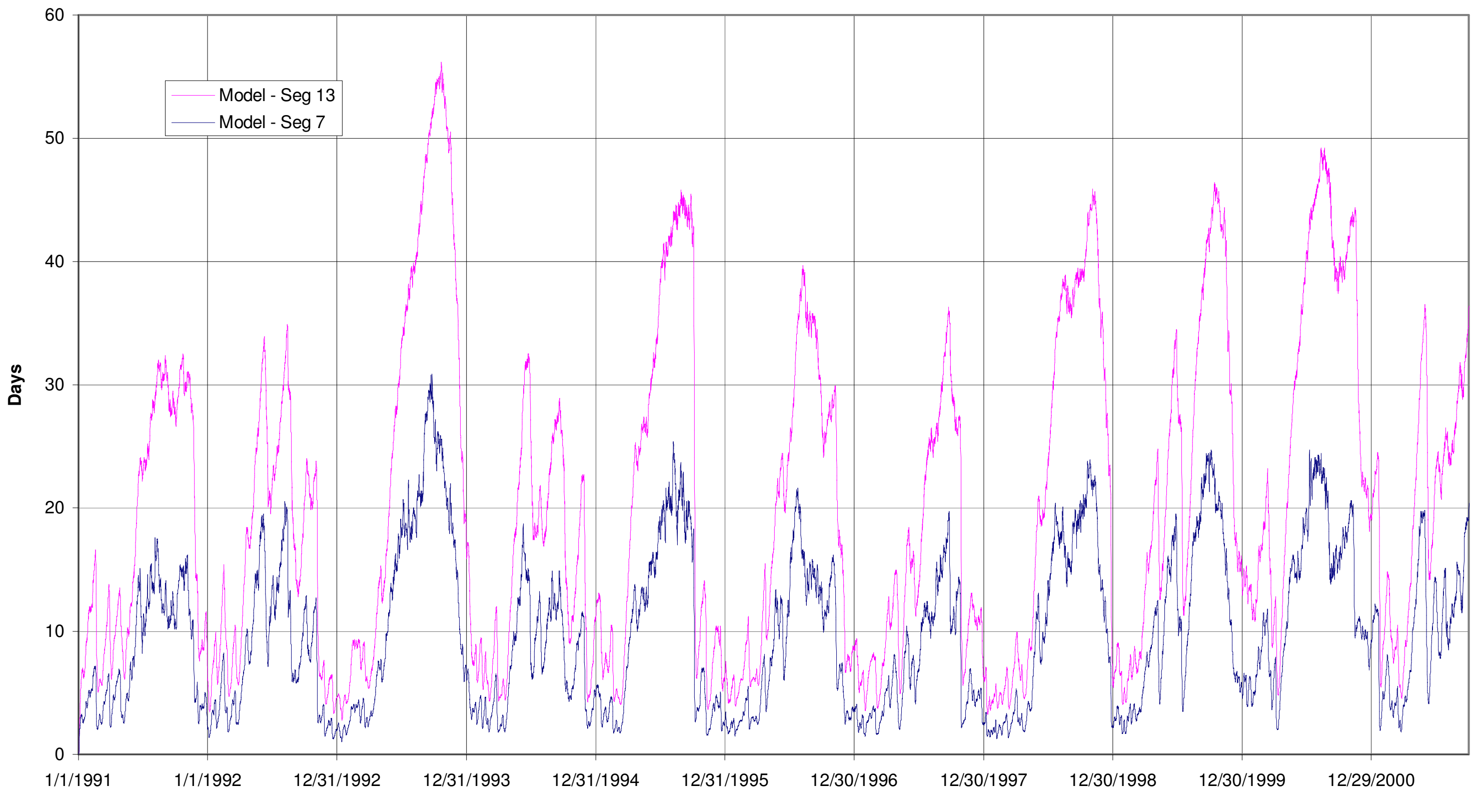
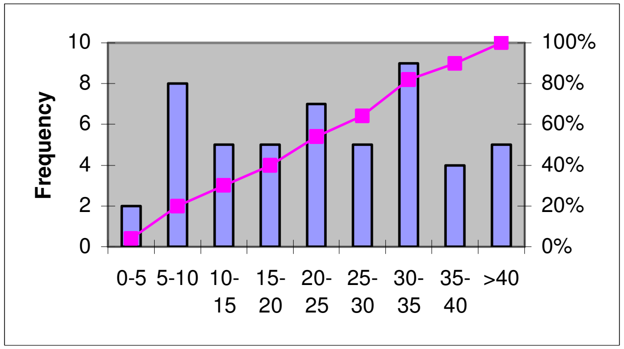


Figure 31 Time series of predicted age of water at the two compliance stations

Observed

Chla Range	*Frequency*	*Cumulative %*
0-5	2	4%
5-10	8	20%
10-15	5	30%
15-20	5	40%
20-25	7	54%
25-30	5	64%
30-35	9	82%
35-40	4	90%
>40	5	100%
	50	



Modeled

Chla Range	*Frequency*	*Cumulative %*
0-5	8	16%
5-10	1	18%
10-15	1	20%
15-20	3	26%
20-25	7	40%
25-30	3	46%
30-35	11	68%
35-40	9	86%
>40	6	98%
	49	

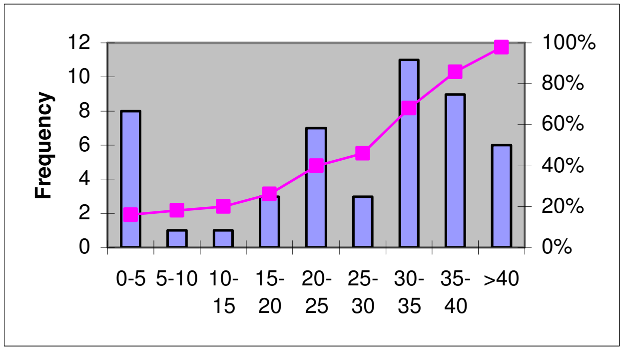
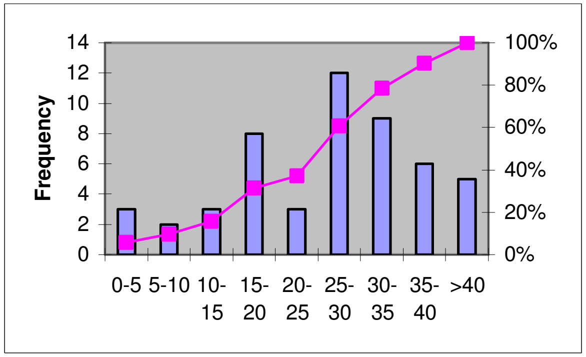


Figure 32 Predicted and observed Chla frequencies at Weiss1

Observed

Chla Range	*Frequency*	*Cumulative %*
0-5	3	6%
5-10	2	10%
10-15	3	16%
15-20	8	31%
20-25	3	37%
25-30	12	61%
30-35	9	78%
35-40	6	90%
>40	5	100%
	51	



Modeled

Chla Range	*Frequency*	*Cumulative %*
0-5	11	22%
5-10	2	25%
10-15	2	29%
15-20	2	33%
20-25	4	41%
25-30	3	47%
30-35	6	59%
35-40	3	65%
>40	17	98%
	50	

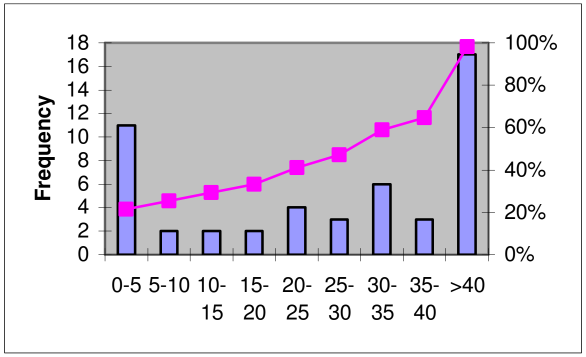
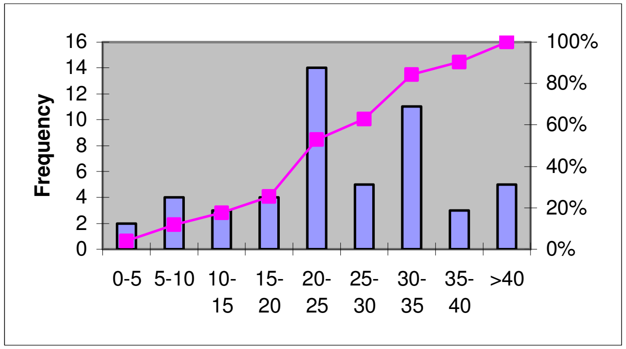


Figure 33 Predicted and observed Chla frequencies at Weiss2

Observed

Chla Range	*Frequency*	*Cumulative %*
0-5	2	4%
5-10	4	12%
10-15	3	18%
15-20	4	25%
20-25	14	53%
25-30	5	63%
30-35	11	84%
35-40	3	90%
>40	5	100%
	51	



Modeled

Chla Range	*Frequency*	*Cumulative %*
0-5	8	16%
5-10	2	20%
10-15	2	24%
15-20	2	27%
20-25	1	29%
25-30	10	49%
30-35	5	59%
35-40	6	71%
>40	14	98%
	50	

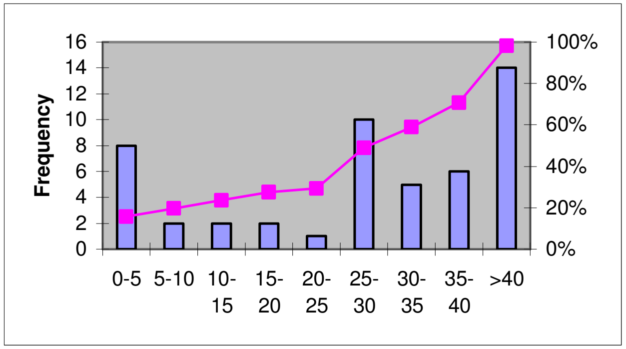


Figure 34 Predicted and observed Chla frequencies for the average of Weiss1 and Weiss2

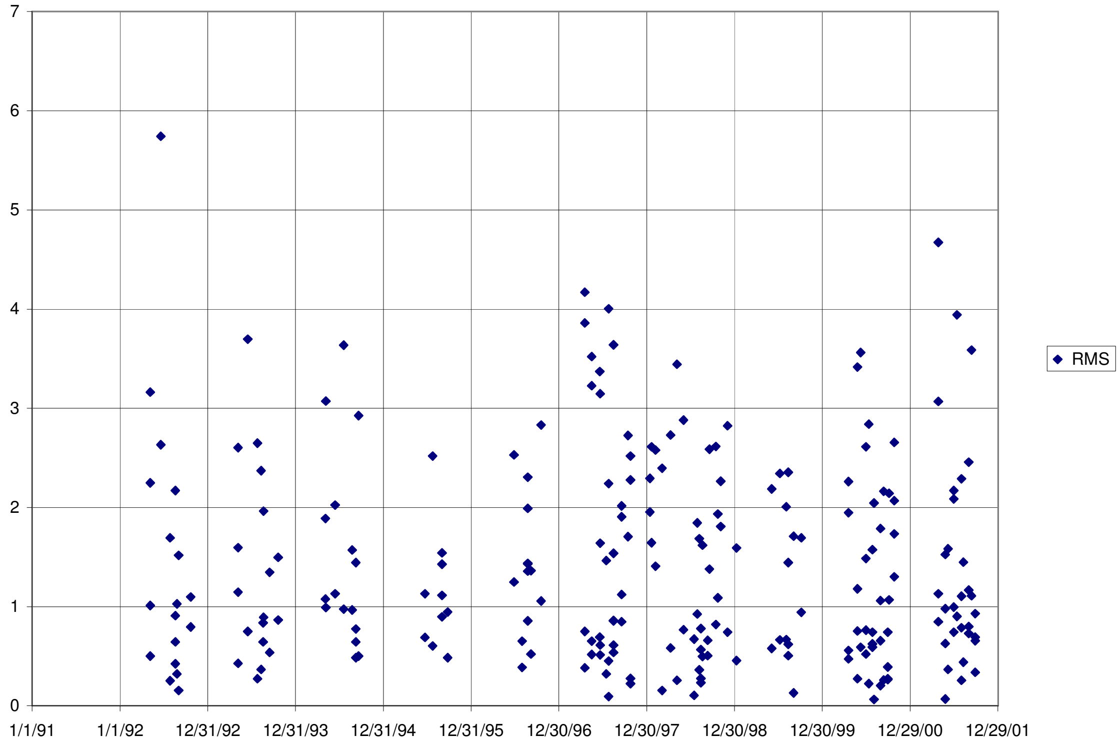


Figure 35 Root mean square statistic for model-observation comparison from each profile vs. the profile date